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Editorial Note

The *Silliman Journal* is pleased to present another issue which focuses on the biological sciences, again including both marine and terrestrial studies. Technical as these papers may appear, I believe there is much here to interest the non-specialist.

While the giant clam species are presently endangered in the Philippines, they also offer much hope for the future of this country. Research at the Silliman University Marine Laboratory and elsewhere continues to pave the way to their large-scale commercial exploitation, in a way that will increase rather than decrease the species' chances of survival. Giant clam farming is becoming a reality!

"An Annotated Checklist of the Taxonomic and Conservation Status of Land Mammals in the Philippines" by Heaney, Gonzales, and Alcala promises to become the definitive reference guide for those interested in the mammals of the Philippines. Note that the authors have included comments on the conservation status of the mammals listed, calling our attention to those pressured or endangered, providing a bench mark for subsequent investigations.

Especially worthy of notice are the last two articles in this issue. "Morphometry and Physico-Chemical Profiles of Lakes Balinsasayao and Danao (Philippines)" by Jones and Delalamon, and "The Climate and Hydrology of the Lake Balinsasayao Watershed, Negros Oriental, Philippines" by Heideman and Erickson, continuing the long series of studies of Lake Balinsasayao published here. The authors of both articles underline the fragile condition of this last significant spot of virgin wilderness in southern Negros, apparently soon doomed to be denuded like the rest of the island. The future looks grim indeed, as hungry and landless peasants, illegal loggers and other exploiters, even armed rebels and their military counterparts all converge on the Balinsasayao area.

D. L.

Notice to Authors

The *Silliman Journal* welcomes contributions in all fields from both Philippine and foreign scholars, but papers should normally have some relevance to the Philippines, Asia, or the Pacific. All submissions are refereed.

Articles should be products of research, taken in its broadest sense; a scientific paper should make an original contribution to its field. Authors are advised to keep in mind that *SJ* aims at a general, international audience, and to structure their papers accordingly.

SJ also welcomes submissions for its "Notes" section, generally briefer and more tentative than full-length articles. Reports on work in progress, queries, updates, reports of impressions rather than of research, responses to the work of others, even reminiscences are appropriate here. Book reviews and review articles will also be considered for publication.

Manuscripts should conform to the conventions of format and style exemplified in this issue of *SJ*. Whenever possible, citations should appear in the body of the paper. holding footnotes to a minimum. Submit pictures only when absolutely necessary. Scientific papers should be accompanied by an abstract. All authors must submit their manuscripts in duplicate, typewritten double-spaced on good quality paper.

The Editorial Board will endeavor to acknowledge all submissions, consider them promptly, and notify authors of its decision as soon as possible. Each author of an article is entitled to twenty-five free offprints. More may be had by arrangement with the editor before the issue goes to press.

GIANT CLAM CONSERVATION IN THE PHILIPPINES

Angel C. Alcala and Sally N. Alcazar

Efforts to conserve giant clam resources in the Central Visayas by clam farming are assessed.

All seven species of clams belonging to the Family Tridacnidae have been reported from the Philippines (Rosewater, 1965, 1982). Recent surveys have shown that three species (The largest species, <u>Tridacna gigas</u> and <u>T. derasa</u>, and the china clam <u>Hippopus porcellanus</u>) exist in small numbers in the southern and southwestern parts of the country but are either extinct or nearly extinct in the Luzon area, the Central Visayas, and the Western Visayas (Alcala, 1986; Juinio et al., 1986). In order to conserve these species, two Philippine laboratories, the Marine Science Institute at the University of the Philippines and the Silliman University Marine Laboratory (SUML), have conducted research in giant clam mariculture since 1984, in collaboration with three other laboratories in Australia, Papua New Guinea, and Fiji. The program is supported by the Australian Center for International Agricultural Research. The captive breeding program hopes to restock protected reefs with juveniles spawned and reared in the laboratory, with the cooperation of artisanal and commercial fishermen. Clam farming thus serves as incentive for coral reef protection, which is also needed in the Philippines because of the widespread degradation of coral reefs.

The present paper describes the initial efforts at SUML to conserve giant clam resources through clam farming in protected reefs of the Central Visayas.

CLAM BREEDING AND REARING AT SUML

Five species of tridacnids have been induced to spawn with serotonin injections or addition of macerated gonads to the spawning tanks. The laboratory has several thousand juveniles of <u>Tridacna maxima</u>, <u>T. squamosa</u>, <u>T. derasa</u>, and <u>Hippopus hippopus</u> for farming purposes. About 2,200 juvenile clams have so far been distributed to 11 groups of fishermen on the islands of Negros, Apo, Balicasag, and Pamilacan. The fishermen-cooperators have grown these clams on protected reefs and have agreed to leave mature animals as breeding stock on the reefs at harvest times. About 50,000 juveniles belonging to five species will be distributed to more fishermen during the next few months.

COOPERATING AGENCIES

In its program of promoting clam farming, SUML has been collaborating with the University of the Philippines Marine Science Institute and has worked with the local fishermen´s organizations, the Philippine Council for Agriculture and Resources Research and Development, and the Central Visayas Regional Project-1. The last named office is promoting the proper management of terrestrial and shallow-water marine resources in the central Philippines. The Laboratory hopes to also involve in the program the Bureau of Fisheries and Aquatic Resources, as well as private individuals.

TECHNOLOGY GENERATION

It is now thought that giant clams may be farmed commercially for both meat and shells. To this end SUML is attempting to develop a technology package for giant clam culture adapted to local conditions in fishing villages. But even before this package becomes available, SUML has been conducting training sessions on giant clam mariculture and conservation among fishermen at two villages in Negros Oriental, in cooperation with the Central Visayas Regional Project-1. The training sessions include techniques of clam spawning, larval rearing and ocean nursery. It is hoped that these sessions will increase the conservation-consciousness of the fishermen, resulting in reef protection and clam farming for economic benefit.

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A PRELIMINARY STUDY OF THE REPRODUCTIVE CYCLE OF Tridacna squamosa Lamarck (BIVALVIA:TRIDACNIDAE) AT CARBIN REEF, CENTRAL PHILIPPINES

Erwinia P. Solis

Results of gonad biopsy of T. squamosa gonads, conducted every 3 to 4 months from September 1985 to September 1986 at Carbin Reef, Negros Occidental, indicated seasonality in spawning. A probable peak of spawning coincided with the wet season and the period of high water temperature, June to September. The presence of clams with mature eggs throughout the sampling period indicates a potential for year-round spawning.

Giant clams are being subjected to increased fishing essure because of their food and shell (Jameson, 1976; Braley, 84). They are now the subject of mariculture efforts in a mber of laboratories in the Indo-Pacific region for the purpose preventing their extinction and augmenting existing stocks for od (Munro and Heslinga, 1981; Fitt et al.,1984; Heslinga et ., 1984). Knowledge of breeding seasons of giant clams must be tained to provide conservationists information they need to pport efficient population management as well as understand the productive success of these animals before the feasibility of a rge-scale mariculture of giant clams can be determined ameson, 1976;Braley, 1984). Tridacna squamosa, one of the tant species in the Philippines (Rosewater, 1965), is being udied for mariculture for food and its colored shell.

Tridacna squamosa, a medium-sized species with shells up to cm in length, is of commercial importance more for its shell an its meat. Known as "hagdanan" or "dagatan" in Cebuano and anlot" in Ilonggo, the colored variety of T. squamosa together th two other species, is the most marketable species of idacnid clams on the Philippine local market (Gomez, 1986). e possibility of culturing T.squamosa, and other species of ant clams, has been studied in a number of laboratories in the do-Pacific (Gwyther and Munro, 1981; Fitt et al.,1984; Heslinga al. , 1984). Spawning cycles based on spontaneous or induced awnings and presence of mature gametes have been observed in e Marshall Islands (Rosewater, 1965), in Fiji (LaBarbera, 75), Palau (Hardy and Hardy, 1969; Beckvar, 1981; Fitt and ench,1981; Heslinga et al.,1984), New Guinea (Gwyther and nro,1981), and Tonga (McKoy,1980).

This study on the reproductive cycle of T. squamosa aims to ntribute to present knowledge of the biology of giant clams; it hoped that the results of the study will have practical plications to giant clam farming. In this contribution, gonad conditions of T. squamosa using the gonad biopsy technique of Crawford et al. (1986) were examined by regular sampling of natural populations at Carbin Reef, located in the Visayan Sea, 10° 59′N and 123° 28′E, northern Negros Occidental.

MATERIALS AND METHODS

Gonad biopsy samples were collected randomly from clams in situ at Carbin Reef in September and December 1985, and in April, June, and September 1986 (roughly at 3-4 month intervals), with the aid of SCUBA. A human biopsy needle was inserted through the mantle, an inch below the exhalent siphon, into the gonad of the gaping clam. Smaller clams (less than 15 cm) required needle insertion of about half an inch or less to hit the gonad. A piece of coral rubble was usually placed in between valves to prevent them from closing, but it was also possible to slowly approach a gaping clam and insert the needle as quickly. Gonadal samples from each clam were placed separately in 10 ml labelled plastic vials filled with clean seawater, and covered. The cover was removed only when a small volume was drawn with the biopsy needle and placed inside the vial. The presence of sperm and eggs can be determined macroscopically. A cloudy sample with small, round, grainy particles indicated the presence of both sperm and eggs; a cloudy sample with no particles indicated the presence of only sperm, while a sample with only small round grainy particles indicated the presence of eggs. This visual procedure made recording easier and saved time. Microscopic examination soon after collection confirmed the presence of sperm and eggs as well as the size and maturity of the latter: spherical eggs with clear, well-differentiated, thin outer membranes indicated maturity; irregular shapes in various sizes indicated the opposite.

The water temperature at every sampling was determined using a field thermometer.

Egg-size was determined from 50 randomly-chosen eggs using a micrometer eyepiece calibrated to 13.2 millimicron per micrometer unit.

In order to assess the reproductive condition of each clam the following data were recorded:

1) egg density of mature eggs from a 10 ml sample,
2) egg size, less or greater than 92 um in diameter,
3) egg shape: proportion of distorted to spherical eggs,
4) presence or absence of a clear, well-differentiated membrane surrounding the egg,
5) presence or absence of sperm.

The stages of the gonad samples were determined following the four-stage classification of Braley (1984) (see below). A fifth category, "male," was added, when only sperm was present:

Developing: eggs up to 92um, generally various sizes but usually tear drop shape in a progressive state,
Ripe/Mature: eggs from 92 um, vitellogenesis complete (ova cytoplasm filled with yolk), dense eggs in the sample,
Regressive: (post spawning) eggs any size but degenerate,
Spent/Resting: lack of gonad in the sample; all "resting" samples were biopsied twice to be certain of the lack of eggs and sperm,
Male: only sperm is present.

The size of eggs considered mature in this study followed LaBarbera (1976), who gave the size range for eggs which developed to metamorphosed larvae from 92.3 to 117.8 um. The number of clams falling in each category was as determined for each sampling month..

Results were subjected to a test of independence using the G-test (Sokal and Rohlf, 1969), to determine whether the frequency of each reproductive condition was the same in any month sampled.

RESULTS

Table 1 summarizes the number of clams biopsied during the ive sampling dates from September 1985 to September 1986, the umber and percentage of clams falling in the four reproductive tages, and data on temperature . The data on percentage of the our reproductive stages and the presence of sperm only are resented in bar graphs (Fig.1). Spawners of this species at arbin Reef peaked in December 1985 (17.6 %) and June 1986 (18). The lowest percentage of clams with ripe eggs occurred in pril 1986 (9.7 %), although ripe eggs were found on all the ates sampled. Developing eggs were present in a large percentage f all samples except in the September 1986 sample. Clams with perm only (which indicated the male phase of the individual, ith eggs in a resting condition) were also present in all the onths sampled. The total absence of gametes (indicating a robable spontaneous spawning before biopsy) occurred in most of he clams in the September 1986 sample, in some in the December 985 and June 1986 samples, but in none in the September 1985 and pril 1986 samples. No clam was found in the regressive condition uring the sampling period. The R x C test of independence using he G-test (Sokal and Rohlf, 1969) was significant at $p<0.005$, ejecting the null hypothesis that there is no difference in the

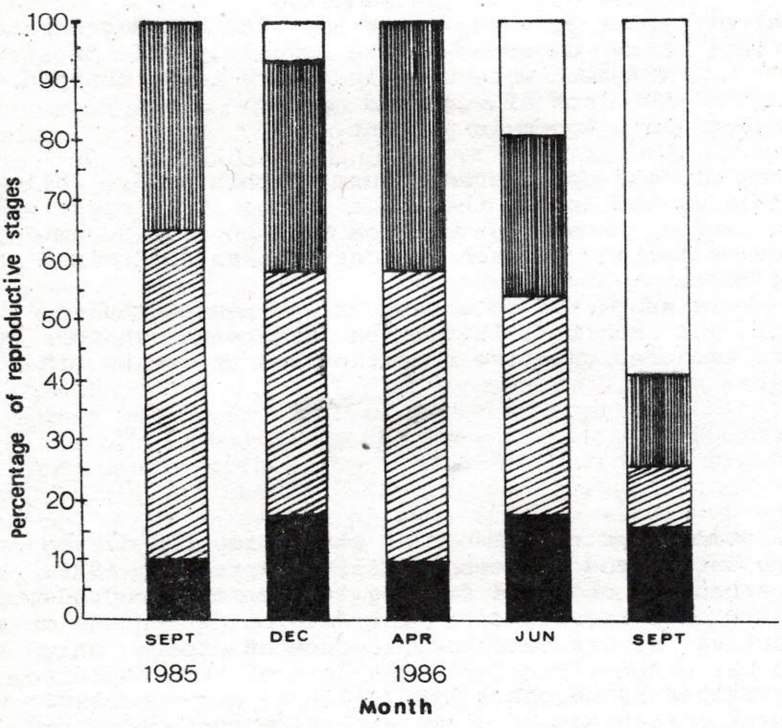

Fig. 1. Percentage of various reproductive stages of gonads in T. squamosa in Carbin Reef, Sagay, Neg.Occ. from Sept. 1985 – Sept. 1986.

Legend: ■ – mature eggs; ■ – developing eggs; ▥ – sperm only; □ – spent; ▨ – regressive.

Table 1. Gonad condition of T. squamosa at Carbin Reef, Sagay, Negros Occidental, Philippines

Sampling Date	No. of Clams Biopsied at Random	Range of Water Temperature (Celsius)	Range of Clam Length (cm.)	Clams with Ripe Eggs		Clams with Developing Eggs		Clams with Sperm Only (immature or resting)		Clams with No Gametes (spent)	
				No.	%	No.	%	No.	%	No.	%
September 1985	20	29.5 - 31.0	11.0 - 24.9	2	10	11	55	7	35	0	0
December 1985	17	27.0 - 27.5	15.6 - 23.0	3	17.6	7	41.2	6	35.3	1	5.9
April 1986	31	27.5 - 28.5	15.4 - 23.9	3	9.7	15	48.4	13	41.9	0	0
June 1986	22	28.0 - 29.0	16.4 - 25.5	4	18.2	8	36.4	6	27.3	4	18.2
September 1986	20	30.0 - 32.0	11.0 - 27.6	3	15	2	10	3	15	12	60

frequency of each reproductive condition on any date sample (aseasonality).

DISCUSSION

Although the data were collected only every three to four months in one year they suggest a peak spawning from June to September, coinciding with the wet season and the period of higher water temperatures (Table 1). Spawning may have commenced in May, for which month I have no data. Our observation of natural spawning on the study reef in June and September provide additional evidence. However, the presence of clams with mature eggs throughout the sampling period indicates that the potential for year-round spawning exists.

There may be a minor spawning episode in December, as shown by a small proportion of clams with spent gonads. This seems to agree with the observations on gonads maturing every five to six months among broodstock clams (*T. derasa*) in Palau (Heslinga, pers. comm.). A similar span of time seems to be required for gonad maturity in a few individuals of *H. hippopus* in the laboratory (unpub. data).

In this study the spawning activity of *T. squamosa* from June through September and in December agrees with the findings of LaBarbera (1986), Gwyther and Munro (1981), and McKoy (1980). However, it is not known whether spawning had occurred in January, February, March, or November, as reported to have occurred in the Marshall Islands (Rosewater, 1965), Palau (Beckvar, 1981; Fitt and Trench, 1981; Heslinga et al., 1984), Tonga (McKoy, 1980), and in the Philippines (unpub. data). The same species may spawn during the same month of the year, regardless of geographical location, but further investigation is needed to establish this. (Jameson, 1976). It is interesting to note that *T. squamosa* spawned in the summer months (December-February) in Tonga (McKoy, 1980), whereas it spawned during the winter months (in July) in Fiji (LaBarbera, 1975). The speculated winter breeding of this species by Yamaguchi (1977) and Fitt and Trench (1981) disagrees with the summer spawning hypothesis of McKoy (1980). These discrepancies, according to McKoy (1980), may result from population differences (either induced or genetic) between Australian tridacnids and those of the more easterly Pacific Islands.

Results of hypodermic extraction of gonads from *T. gigas* and *T. derasa* on the Great Barrier Reef suggest a potential early to mid-austral summer spawning for the former and to a lesser degree for the latter, indicating the presence of seasonality for these species in Australia (Braley, 1984).

Although the factors influencing gonad maturity and the initiation of spawning *in situ* are not known, the abundance of food supply and other environmental factors could bring about avorable conditions. (Birkeland, 1982, cited in Braley, 1984). he ability to ovulate might be related to lunar or seasonal ycles, but this is not yet well understood (Munro and eslinga, 1982). A strong case can be made only for seasonality, or which temperature, phases of the moon (tides), and water otion have all been implicated, but which are supported by onflicting evidence (Rosewater, 1965; LaBarbera, 1975, Jameson, 976, Beckvar, 1981). It is believed that in nature, different ocal environmental cues, varying from place to place, may rigger gonad maturation and spawning (Fitt and Trench, 1981). irkeland (1982) suggested that if high rainfall affects hytoplankton bloom by increased availability of nutrients from errestrial runoff, then there would also tend to be a easonality in the spawning of tropical marine invertebrates as xhibited by their temperate counterparts.

Heslinga and his colleagues (1984) called for an assessment f the importance of spawning "seasonality" in tridacnids and its otential role in limiting hatchery production. They claimed that ost previous studies were too brief to substantiate claims of he supposed seasonal "peaks" in spawning intensity. Although ome of the conflicting data in tridacnid spawning behavior may eflect real latitudinal variation, it is still premature to onclude, as Yamaguchi (1977) did, that giant clams are haracterized by seasonal breeding peaks (Heslinga et al., 1984).

The short duration of the study did not allow the etermination of an annual, repetitive spawning cycle of this pecies as Jameson (1976) reported. Although spawning may be easonal for a given species, the actual time span of spawning ay vary from one year to another and may occur for only a brief eriod (Stephenson, 1934; Fitt and Trench, 1981). Until factors nfluencing gonad development are determined, successful nduction of normal spawning for experimental or maricultural ork will depend on the investigator being in the right place at he right time (Fitt and Trench, 1981).

CONCLUSION

Although there was probably a peak spawning period for *T. squamosa*, the presence of spawners throughout the sampling period ndicates that a potential for year-round spawning exists. This ooks promising for mariculture of this species, as availability f spawners would not limit hatchery production. Spawning nduction for mass production of juveniles may be done during the eak spawning period and larval rearing during the rest of the ear.

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NOTES ON THE MICROHABITATS OF THE PHILIPPINE DISCOGLOSSID FROG *BARBOURULA BUSUANGENSIS*

A. C. Alcala and W. C. Brown

The microhabitats of the Philippine discoglossid frog *Barbourula busuangensis* in permanent mountain streams in northern Palawan are described. The water temperatures of these streams were about 25° C or lower. The juveniles were found in quiet, shallow pools, under rocks and among rotting leaves; the adults, under large boulders and inside crevices of rock-walls. The microhabits of adults were all directly above water. Several species of anuran amphibians were associated with *Barbourula*.

The discoglossid frog *Barbourula busuangensis* from the Philippines was desc·ibed as a new genus and species from Busuanga Island, north of Palawan Island, by Taylor and Noble in 1924. The type was the only known specimen. In the sixty years since that time there have been few additional collections of this frog; and no data has been published on its natural history other than that of Myers (1943), who noted that specimens collected by Albert Herre, also on Busuanga Island in 1940, were taken from pools in two mountain streams at an elevation of 200 plus meters. They were first seen as floating with only the eyes and nostrils above the surface of the water. When disturbed they swam to the bottom and hid under stones. This collection by Dr. Herre was the second record for the species.

The third record, also from Busuanga Island, was a collection by members of the 1946 Zoological Expedition to the Philippines conducted by the Field Museum of Natural History in Chicago. The fourth collection, by the Stanford University - Silliman University Expedition in 1961 (Brown and Alcala, 1970), provided the first record for Palawan Island. Specimens were taken from a large pool in the Malatgaw River at an elevation of about 500 meters on the side of Thumb Peak near the center of the island, west of Puerto Princesa. However, no information about their microhabitat or behavior was obtained, because the specimens were found dead, along with dead fish. The deaths were the result of the local inhabitants having poisoned the pool with an insecticide (Endrin) in order to obtain the fish. No other specimens of *Barbourula* were taken by members of that expedition, although about two thousand amphibians and reptiles were collected in the lowlands and mountainous area around Thumb Peak over a period of several weeks.

In 1978 a second species of the genus, Barbourula kalimantanensis, was described by Iskander (1978) from northern Borneo. The unique type of this species was from a mountain stream, the same general habitat as that known for the Philippine species. These infrequent collections, always in mountain stream habitats, as well as the general appearance and extensively webbed fingers and toes, provided the basis for the view that this was a very secretive, aquatic frog.

Inger (1954:212) noted that eggs in the ovaries of gravid females were relatively low in number, large and without pigment. He suggested that they might be deposited under stones in the creek beds.

It is of interest, however, that no larvae associated with this species have ever been found in the mountain streams where adult populations are known. This led Brown and Alcala (1983), in their review of modes of reproduction of Philippine anurans, to speculate that this type of egg is an adaptation to a very specialized mode of reproduction, perhaps one lacking an aquatic larval stage. This conjecture was based on the similarities in number, size and appearance of the eggs to those of Philippine species in the genera Platymantis (Ranidae), Philautus (Rhacophoridae) and Oreophrne (Microhylidae). All of these species deposit eggs in sites outside of the water. The larvae for some species undergo direct development in the egg capsules at the deposition site; those of other species escape from the egg capsules and make their way by various means to a nearby body of water.

For a period of three weeks in June 1984 a six-man field-party from Silliman University, Dumaguete City, Philippines and the California Academy of Sciences, San Francisco, California collected in the Tinitian-Langogan area, northern Palawan Island. The survey took the party from sea level to an elevation of about 700-800 meters on forested mountains. One objective was to find and study a population of Barbourula. A few hundred amphibians and reptiles were taken, but unfotunately the collection included only a single example of Barbourula busuangensis. This was a juvenile taken from a pool in Arotayan Creek, a tributary of the Langogan River. Arotayan Creek and other tributary creeks of the Langogan River appeared to be mildly flooded at the time, and it was surmised that the high water may have made it difficult to find other individuals of this species. But the finding of only one specimen served to strengthen the view that Barbourula is a very secretive, primarily aquatic frog.

In late March 1985 the senior author and Braulio Gargar made a trip to the Langogan River area to again search for Barbourula. The month of March is in the middle of the dry season and is a favorable time for such field work. The objective was to locate populations of this frog and collect at least 20 individuals for a proposed captive breeding program at Silliman University. It was also hoped that observations might be made on its microhabitats and general behavior. We report these observations in the present paper.

METHODS

Stream-bed transect-surveys to elevations of about 300 meters were carried out in Arotayan and Bolo-bolo Creeks, which empty into the Langogan River on opposite banks some five to six kilometers above the mouth of the river. Arotayan Creek was a relatively shallow creek; the flow was more or less uniform along the gradual slope of the stream bed. Bolo-bolo creek had a more deeply cut, steeper stream bed, with deeper pools (about one meter deep). This stream was bordered by extensive rock walls in the upper segment of the transect. There were large boulders at various locations in both streams, and quantities of leaf litter tended to cover the pools.

The transect along Arotayan Creek was about 1.7 km and along Bolo-bolo Creek, about 0.75 km. Collecting stations were established about every 190 meters (300 steps), resulting in five on Bolo-bolo and 10 or Arotayan Creek. Two trips were made along each transect between about 1500 and 2030 hrs on different days. Vegetation cover was noted, and at each station water temperatures were measured. Samples of the species of frogs found along the streams were collected and their habitats noted. In the case of Barbourula, which we wished to keep alive, all specimens were placed in wet cloth bags containing rotting leaves at the collecting site. At camp, animals were transferred to small basins with water, rocks, and leaf litter and enclosed within a netting material to prevent escape. The frogs were later returned to the wet cloth bags for transport to Dumaguete City, which took four days. They were fed with termites every night from the time they were transferred to the field containers, throughout the period of transport. Collected specimens of the other species were killed and preserved at the collecting site.

RESULTS

Water temperature. At station 1 on Arotayan Creek the temperature of the water was 29°C; at station 10, at the upper end of the transect (elevation about 300 meters), 25°C. The decrease in temperature between stations ranged from about 0.2 to (mean change 0.4) , as elevation increased. On Bolobolo Creek at station 1 the water temperature was $27.3^{\circ}C$, and $25^{\circ}C$ at station 5, a mean change of about 0.46 between stations along the steeper gradient of this creek.

Frog species. Aside from *Barbourula*, both creeks harbored populations of several frog species. These included *Staurois natator*, *Rana signata*, *Rana microdisca*, *Rana magna*, *Rana sanguinea*, *Ooeidozyga laevis*, *Chaparina fusca* and *Bufo biporcatus*. One juvenile *Leptobrachium hasselti* was taken from Arotayan Creek. Unidentified ranid tadpoles belonging to three species were also collected.

The most common species was *Staurois natator*, represented by both juveniles and adults, mostly the former, and including newly metamorphosed individuals. *Rana signata*, *Rana magna*, *Rana microdisca*, and *Bufo biporcatus* were fairly common. *Ooeidozyga laevis*, *Chaparina fusca*, and *Leptobrachium hasselti* were less common or even rare. *Ooeidozyga* was found only in the lower portions of both creeks and not at the uppermost stations. *Barbourula* was found only at station 5 on Bolo-bolo Creek and stations 9 and 10 on Arotayan Creek, the highest stations. The juvenile of this species which was taken in 1984 near station 5 on Arotayan Creek had most likely been carried down by water current, as a thorough search at this station in 1985 produced negative results. In contrast, *Ooeidozyga laevis* was found only at the lower stations along each transect. Other species had ranges all along the transects.

Microhabitats and Habits of *Barbourula*. We collected a total of 22 *Barbourula*, including a 13-mm newly metamorphosed juvenile. We saw 10 other individuals, mostly large ones, but failed to catch them. Smaller specimens (all presumed juveniles) and large adults occupied different microhabitats. Juveniles were observed under rocks and among rotting leaves in cool, relatively quiet, shallow pools of the two streams. When not disturbed, these young animals stayed mostly in the water, with only their eyes and nostrils out. Occasionally, a juvenile was seen on the top of floating leaf litter. On the other hand, large individuals, presumably all adults, were observed under large boulders, usually with streams of water underneath, or inside rock crevices in the bordering walls on Bolo-bolo Creek at the level of the water or even above the water. At night these large animals were observed to emerge and stay at the entrances of these crevices, which usually led to water. Presumably they were feeding. Two of the four large adults collected were taken from crevices and the other two from undersides of boulders. Six more large adults were seen in rock crevices but were not collected. In contrast, all smaller frogs were taken from pools drained by slow-flowing streams. Adult frogs, despite their habit of getting out of the water at times, can be considered aquatic.

It is also interesting to note that adults and juveniles differed somewhat in coloration. Live large adult frogs are blackish above with fading crossbars on the limbs. Juveniles are in general lighter-colored, being whitish to yellowish brown, with blackish spots above. The color pattern makes it difficult to spot young frogs against a background composed of a mosaic of dark and light rocks on the bottom of pools. Similarly, adults, which are dark, are difficult to distinguish from the blackish rocks among which they hide.

DISCUSSION

Barbourula kalimantanensis, based on data for the unique type, occupies a similar habitat to that of *B. busuangensis*. The former was found beneath a large rock in the forested Rincon River in northern Borneo (Iskander, 1978). Thus far, all of the data indicate that the species of this discoglossid genus are limited to rocky microhabitats in mountain streams.

Tadpoles have never been observed, but the collection in 1985 of a small 13-mm juvenile, which had probably just metamorphosed, indicates a breeding season extending to the drier months. Although no eggs have thus far been found, the finding of this juvenile, as well as the observation that the habitats of adults are under large boulders in the beds of mountain streams or crevices bordering rock walls, provides supporting evidence for the speculations of Inger (1954) and Brown and Alcala (1983). It is possible that eggs might be attached underneath boulders along the stream banks or deep in crevices in rock walls, where they undergo direct development. Newly hatched individuals of very small size (note the 13-mm measurement above) could then enter the creek fully metamorphosed. This scenario has a parallel in the mode of development exhibited by the ranid frog *Discodeles guppyi* from the Solomon Islands (Boulenger, 1887).

Why is *Barbourula* limited to the uppermost stations and *Ooeidozyga* to the lower stations? One suggestion is that the former is stopped by water temperatures higher than 25 C. But is the latter species limited by low temperatures, resulting in its failure to co-exist with the former species in the upper stations? Observations elsewhere tend to rule out low temperature as a factor, since Ooeidozyga ascends to 1,000 m altitude on Negros Island, where temperatures are in the lower 20's.

Another possible reason, indicated by our observations, is competition for space and/or food. Both young *Barbourula* and young and adults of *Ooeidozyga* are found in similar situations in shallow pools with leaf litter. The two species have a similar habit of staying almost submerged, with only their snouts and nostrils out of the water. Both species appear to take similar food items, which they capture in the water or at the edge of pools.

As of June 1986, a year after returning the live collection of Barbourula to appropriately prepared tanks at the Biological Laboratories at Silliman University, 20 specimens are still alive and healthy, as are the two juveniles which were shipped to the Herpetoloty Department at the California Academy of Sciences. No breeding activities have been observed, neither have eggs been deposited by any of the adults, even after injection with hormones. Thus, assuming that the series of four adults originally collected and others that may have reached maturity in the interim includes both males and females, it appears that we have not established appropriate breeding conditions in the laboratory. It is important that a captive program be initiated in order to ensure the survival of this species, which is threatened with extinction as a result of the continuing forest destruction on Palawan and nearby islands.

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OBSERVATIONS ON REPRODUCTION AND BEHAVIOR OF CAPTIVE PHILIPPINE CROCODILES (Crocodylus mindorensis Schmidt)

A. C. Alcala, C. A. Ross, and E. L. Alcala

A breeding facility for the endangered Philippine Crocodile (Crocodylus mindorensis Schmidt) was established in 1980 at Silliman University, Dumaguete City, Philippines. As of February 1984, the breeding program has produced 21 surviving juveniles ranging from hatchling to 3 years of age. Observations on the behavior of those captive adults and juvenile crocodiles are described. Courtship, mating and nest building occurred each year between January and May. Eggs were laid variously between April and August during the years 1981-1984; with multiple clutches by the same female in 1981 and 1982. The mean clutch size was 15.7 (range: 7-25). The incubation period was 77 to 85 days. The female remained near the nest during incubation, and for that period and a few months thereafter was very aggressive. Vocalization of pipped young cued the female to open the nest and transport the hatchlings or eggs to the water. Hatchlings and young were very wary of human intruders. Fighting among the young resulted from close confinement.

Key words: Crocodylus mindorensis, Philippine Crocodile, endangered species, breeding, incubation, hatching, behavior.

The Philippine or Mindoro Crocodile (Crocodylus mindorensis), has generally been treated as a subspecies of the New Guinea Crocodile (Crocodylus novaeguineae) by most authors. However, Neill (1971), and Wermuth and Mertens (1977) recognized it as a distinct species on the basis of cranial features and cervical and lateral squamation. We follow the latter view.

The Philippine Crocodile was once widely distributed throughout the Philippines on the islands of Luzon, Samar, Masbate, Mindoro, Negros, Jolo, Mindanao, and Busuanga; but the species is now severely depleted, being represented by only a few relict populations (Ross, 1982a, 1982b; Ross and Alcala, 1982). One population is known from the upper Pagatban River on Negros Island. Two other populations are on Mindanao: one in Calarian Lake in Zamboanga City and one at Liguasan Marsh in Midsayap, North Cotabato Province (Ross and Alcala, 1983). We believe that small populations still exist in Lake Naujan on Mindoro Island, in the Nabunturan area in Davao del Norte on Mindanao Island

Ross and Alcala, 1983), and in the headwaters of the Ilog River in southwestern Negros (report from local residents). We estimate that these wild populations total no more than a few hundred individuals, although we lack data other than occasional reports and some personal sitings.

In addition, there are 42 known animals in captivity in the Philippines, twenty-five (4 adults and 21 juveniles) are at the facility described here. Another 17, mostly adult, captive animals are owned by private individuals on the islands of Luzon and Cebu, and in Negros Occidental. A few individuals also exist in captivity elsewhere.

This paper describes aspects of reproduction and behavior of adult and juvenile C. mindorensis at the Silliman University crocodile breeding facility during 1982-1984.

MATERIALS AND METHODS

In 1980 a crocodile breeding facility was established at Silliman University, Dumaguete City, Negros Oriental, Philippines. The purpose of this facility was to provide a suitable breeding habitat for the propagation and rearing of captive C. mindorensis. Due to the probable high mortality in the wild, progeny of this program will be retained at the facility for the first few years of their life. If suitable, protected habitat is later available, these offspring may then be liberated into the wild or incorporated as additional brood stock.

The oval-shaped (15.0 x 11.6 m) breeding pen is located adjacent to the University's Marine Laboratory about 2 km north of the main campus. It is enclosed by a 1.9 m high fence with a 9 cm thick, reinforced concrete base buried 10 cm deep. The concrete projects upward and is topped with an imbedded 1.2 m metal fence that inclines inward about 20 degrees. A large rectangular pond (11.1 x 3.8 x 1.3 m) is situated slightly to one side on the longer axis of the pen. The pond walls are concrete and the bottom is mud. Water depth is kept at about 1 m by addition of fresh water. A concrete incline allows the animals easy access to both water and land. Three small, shallow, concrete ponds were also built in the pen, each large enough to accommodate one adult crocodile. The land-to-water ratio in the pen is about 3:1. Pond water is changed every few months by pumping. During high tides, sea water 50 m away seeps into the large pond, making the water somewhat salty, about 5 ppt. Water temperature in the pond varies from 25^{o} to 32^{o}C. Trees surrounding the pen are pruned to assure sufficient direct sunlight for the animals at all times. Space is available in the

Marine Laboratory for incubating eggs and for the care of young animals.

The captive brood stock consists of three adult females and one male. The first female was captured when about a year old in early 1971 from the Pagatban River, southern Negros; she reached sexual maturity in 1981. The second female was acquired in July 1982 and the third in August 1984. The male was donated to the facility in 1980, and was estimated to be at least 15 years old (Ross, 1982b, 1982c). On 18 September 1980, the first female measured 1.3 m in total length and weighed 14 kg; the male measured 2.1 m and weighed 47 kg. Both animals were introduced into the breeding pen at the same time on this date. The second female measured 1.5 m in total length and weighed 24 kg; the third, 1.7 m and 27 kg, at the time of acquisition.

Daily behavioral observation of the penned adults began shortly after their confinement at those times when maintenance and care services were performed. In addition, there were ten 24-hour observation periods from 1981 to 1984. Observations of the behavior of hatchlings and juveniles began in 1981.

Some eggs (N=22) from the 1981, 1982, and 1983 clutches were incubated in the laboratory in an artificially constructed nest of moist humus and leaf litter, with a 50-watt bulb as an external heat source. The orientation of these eggs, as observed in the natural nest, was maintained in the laboratory. We hastened the hatching process of laboratory incubated eggs by enlarging the punctured end of eggs once hatching had begun.

RESULTS

Breeding Behavior and Nest Building

The breeding season of the Philippine Crocodile in captivity was observed from 1981 through 1984. Courtship and mating began in January and continued until about May. This period of time includes the driest season in southeastern Negros. Matings occurred usually between 0400 and 0700 hrs. While in the water the female emitted a series of brief high-pitched groaning or bellowing sounds. The male responded by joining the female in the pond, usually after producing similar but lower-pitched sounds. In the water, the female performed such movements as rubbing its snout on the male's head and swimming over and under the male for as long as 30 minutes, while continuing to vocalize. Copulation followed. In this process, lasting a few seconds, the male mounted the female and presumably lowered his tail under the female's tail to effect intromission. After copulation both male and female usually remained in the water for some time. Nest building began as early as 10 February in 1984, 27 February in

1982, and about the first of March in 1981 and 1983, an generally continued until a week before egg-laying in Apri (1981-1983) and May (1984).

Only the female built the nest, using the same site durin the four years of study. A mound-type of nest was constructe from a mixture of sand and plant material (mostly the latter) consisting of dry grass, rotting leaves, and twigs. The female facing away from the nest, used primarily its hind legs t "shovel" dirt to the nest site. Nest building occurred for brie periods of time during the day and at night, but mostly at night This activity continued from February through April or May. Th nests varied in size from about 1.5 to 2.0 m on the short axi and from 2.0 to 2.7 m on the long axis. Nests in each instanc were about 0.5 m high. The nesting materials were compact probably as a result of the female frequently lying on top of th nest.

Oviposition and Clutch Caracteristics

Multiple clutches were laid by the same female in 198 (April, June, and August) and 1982 (April and August), using th same nest each year, for annual totals of 32 and 33 egg respectively. Single clutches of 20 (April 1983) and 25 (Ma 1984) were laid in the following years. The average of these clutches was 15.7 (range = 7-25) with an annual mean of 27.5 Oviposition occurred at night or in the early morning. The egg were deposited in about three layers in the egg chamber, whic was excavated by the female near the center of the nest. Thi was later covered with a layer of rotting leaves about 15-18 c thick.

The eggs were hard-shelled, elliptical, smooth, and white Eggs subsampled from the 1981 production (N=14) wer substantially smaller and lighter and more variable in weigh than subsamples from the successive two years (N=14). The value of these subsamples were as follows: for 1981, axial length 66.5 ± 3.01 mm (range = 62-72, N=14), axial width = 38.8 ± 31.4 (range = 37-41, N=14), mass 60.7 g ± 14.8 (range = 32.5 -74.5 g N=9); and pooled values for 1982-1983, axial length = 70.9 ± 2.1 (range = 67-75, N=14), axial width = 43.1 ± 2.48 (range = 40-46 N=14), mass = 81.5 ± 3.12 (range = 74-86 g, N=14). Difference in axial length, axial width, and mass between the 1981 and 1982 1983 samples were statistically significant (t=4.53, df=26 P=<.001; t=7.0, df=26, P<0.001; t=424, df=21; P<.001).

At substrate (egg chamber) temperature of 28-33^{o}C (mean 30.6^{o}C) for 32 records taken at different times of day for bot laboratory and naturally incubated eggs, the incubation varie from 77 to 85 days, with a mean of 81 days. In any one clutch eggs differed in incubation period by as much as eight days Only 63 of 110 (57%) of the eggs for the four years were fertile Of these, 32 (51%) hatched; and, as of late 1984, 21 offsprin survived.

Hatching of the 1983 clutch was observed and photographed. The female began opening the nest at about 0430 hrs. on 5 July by excavating it with her fore and hind limbs. She then took the eggs or hatchlings one at a time in her mouth and transported them to the water (Illustrations A and B). Of 11 hatchlings, seven hatched at the nest site and four after the female reached the water. One egg contained a near-term young and was not hatched by the female. It was removed from the nest, taken to the laboratory and broken to release the young.

Observation of hatching of eggs incubated in the laboratory provided the following data. The young inside the egg shells produced croaking sounds at hatching time, especially when the eggs or substrate was disturbed. Similar sounds were also heard at the nest site a few hours before hatching in one instance, 26 June 1982. The first visible sign of hatching for laboratory-incubated eggs was the emergence of the snout at one end of the shell. A jerky forward thrust of the animal propelled the head, body, and part of the tail out of the shell within the next few minutes. The hatchling moved forward quickly when stimulated, vocalizing at varying intervals and dragging the shell to which it was connected by the embryonic membranes. The embryonic tissues remained attached for about an hour before the animal broke free of them. One hatchling bit the tissues to free itself. Three out of five young had not been able to hatch spontaneously 12-15 hours after they were heard to croak. Whether they could have hatched on their own without assistance from us is not known.

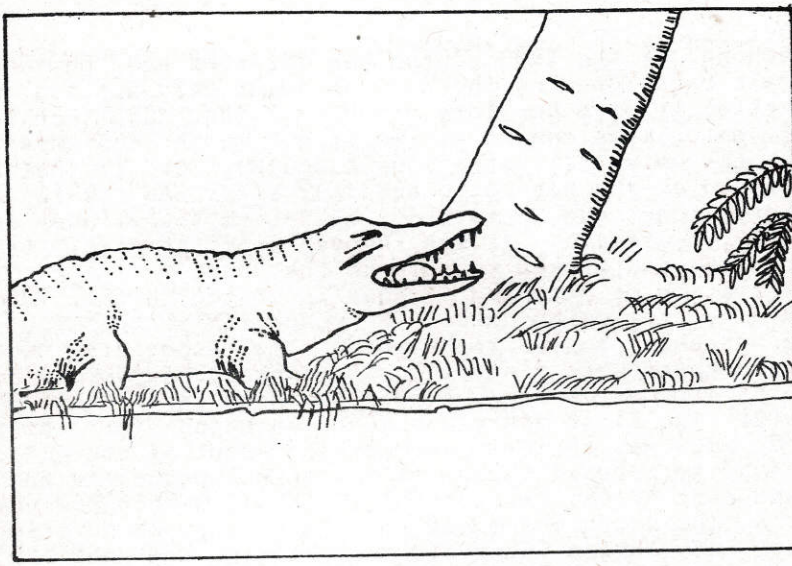
Behavior of Adults

In a typical 24-hour day the female spent about 18 to 19 hours in the immediate vicinity of the nest, 12 to 13 of these hours (0600-1900±) in repairing the nest, moving around the nest, chasing intruders, and lying on the nest. The remaining 5 to 6 hours (0100-0700±) were spent swimming in the pond with the male and sometimes included mating activities.

Aggressive behavior was first observed in the female about two weeks before egg-laying, increasing in intensity as incubation progressed. It was maintained for about three months after hatching. The female lunged at human intruders coming within four or five meters of the nest. When attacking, it opened its mouth and made hissing sounds. The male did not show behavior of defending the nest.

Aggressive Behavior toward other Crocodiles

The female exhibited aggressive behavior toward human intruders as well as toward a conspecific female and a salt water crocodile (*C. porosus*) housed in an adjacent pen. A second female *C. mindorensis* later released into the pen in July 1982,



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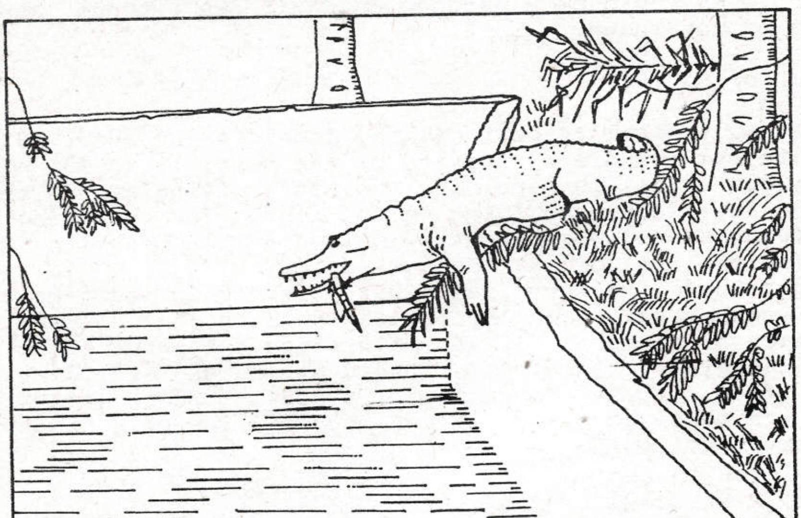

B

was also immediately attacked by the resident pair. They inflicted severe wounds on the tail region of the newly-introduced female, which was then removed from the breeding pen. This female was again attacked by another female when they were placed together in a cage in late 1984.

Hatchling and Juvenile Behavior

Hatchling as well as juvenile C. mindorensis were very wary of human intruders, and dove into the pool or immersed their whole bodies in water at the approach of people. During the first year of life, the juveniles appeared to tolerate each other when confined in small concrete tanks measuring 1 x 2 m. However, three (age 2) animals sharing the same space fought viciously, resulting in the death of two animals. Thereafter, these and older juveniles were kept in larger quarters without serious fights. Since the earlier serious fights leading to injury occurred during non-feeding times, they were probably related to crowding and not to competition for food.

DISCUSSION

The courtship, nest building and mating season (January to May) exhibited by the captive C. mindorensis, which continued for about the same period each year, includes the driest season in this part of Negros. Webb, 1980:107, notes that C. johnstoni in the Northern Territory of Australia also build their nests during the dry season, in August in that region. The type and size of nest built by C. mindorensis is similar to that reported for C. novaeguineae by Neil (1971:402). An egg chamber within the nest, similar to that of C. mindorensis, was reported by Webb (1980:107) for C. johnstoni.

Oviposition occurred from April to August, 1981 and 1982 (years of multiple clutches), and in April 1983 and May 1984 (years of single clutches). The earlier dates of oviposition are in the dry season, but the later dates are not. Neither the late dates nor multiple clutches can at this time be correlated with any weather factor or any obvious change in our maintenance of the breeding facility. Jeff Lang (personal comm.) attributes multiple clutches in C. palustris to overfeeding of the female.

The total number of eggs (32 and 33) in the years of multiple clutches was slightly higher than the number (20 and 25) for years in which single clutches were laid. However, the latter numbers or even the average 27.5 for the four years is close to that (23-25) given by Neil (1971:402) for C. novaquineae, a crocodile of about the same size. The clutch-size (12.6 ± 3.1) reported for C. johnstoni (Webb, 1970:107) is about half of that which we found for C. mindorensis. Reported mea clutch sizes for other crocodilians range from six i Osteolaemaus tetraspis to about 60 in C. porosus and C. niloticu (Greer, 1975). The sizes and mass of the eggs of C. mindorensi are also close to measurements given by Jelden (1981) for C novaeguineae and for C. johnstoni (Webb, 1980:107), and smalle and lighter than similar measurements of eggs of C. porosus. Clutch size, egg size, and mass are probably a function of femal body size.

Our observed incubation period (77-85 days) for C. mindorensis, under the conditions at the breeding facility, agrees closely with that of Joanen and McNease (1980) for Morelet's crocodile from the Mexico-Guatemalan area, is slightl shorter than the 84-91 days reported by Webb (1980:107) for C. johnstoni and is much shorter than the 94-120 day incubatio period which they report for the West African dwarf crocodile.

A comparison of hatching success for our clutches of eggs of C. mindorensis with hatching success reported for other species shows slightly less variation. Hatching success in Morelet's Crocodile varied from 10 to 69.3%, as computed from the data of Hunt (1980). In the West African Dwarf Crocodile, hatching success of incubated eggs ranged from 7 to 93% (mean, 46.5%) for six groups of eggs (Tryon, 1980) In the American Alligator, the hatching rate of incubated eggs was 72% for eggs from captive animals and 94% for eggs taken from the wild when infertile eggs were deleted from the analysis (Joanen and McNease, 1980). Factors affecting hatching success are not clear from the data available.

Crocodilus mindorensis, like C. niloticus and C. porosus (Pernetta and Buegin, 1983), opens its nest and carries the hatchlings to the water. The male C. mindorensis, however, apparently does not participate in the transport of hatchlings, as do males of some other crocodilian species (Hunt, 1980; Pernetta and Burgin, 1983; Tryon, 1980; Joanen and McNease, 1980).

Vocalization of the young probably stimulated the female to open the nest and help hatch the eggs, as has been reported for the American Alligator (Joanen and McNease, 1980), Morelet's Crocodile (Hunt, 1980), and C. johnstoni (Webb, 1980).

The aggressiveness toward intruders, observed for the Philippine Crocodile at the breeding facility, may have been abnormal, modified by conditions imposed as a result of captivity. However, parallel aggressiveness has been observed in other species. The intensity of the defense reaction of crocodiles varies according to species and between individuals of a species (see Tryon, 1980). Neill (1971:399) mentioned that females of C. novaeguineae in the wild guarded their nests but did not defend them against human intruders. Pernetta and Burgin (1983) stated that nests of both C. porosus and C. novaeguineae were guarded by the females.

The aggressiveness of our original captive female C. ndorensis toward other conspecific females placed in the eeding facility pen at later dates may indicate that a one-to-e sex ratio is the ideal one for captive breeding, as seems to e the case for the American Alligator (Joanen and McNease, 71). However, the size of the enclosure may prove to be a ctor, as was demonstrated for juveniles when the increase in e size of the confining pen was shown to reduce fighting etween occupants.

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DISTRIBUTION OF ZAOCYS LUZONENSIS (SERPENTES:COLUBRIDAE) IN THE VISAYAN ISLANDS, PHILIPPINES

Charles A. Ross, Angel C. Alcala, and Rogelio V. Sison

The Philippine endemic snake, Zaocys luzonenis, was found to exist in various regions of the Visayas.

The two species of the Philippine snake Zaocys were recently reviewed by Leviton (1983). Zaocys carinatus is a widely distributed species in southern Asia, but is restricted to the island of Palawan in the Philippines. Zaocys luzonensis is a poorly known Philippine endemic.

Leviton (1963, 1983) questioned the only previous record of Z. luzonensis for the Visayan Islands (Leyte Island, eastern Visayas, Taylor, 1922). Taylor (1922) based this record on a list of material received at the Herpetologische Sektion, Museum der Senckenbergischen Naturforschenden Gesellschaft in Frankfurt am Main, from Konsul Dr. O. Fr. von Moellendorff, given in the Bericht uber die Senckenbergische Naturforschende Gesellschaft for June 1889 to June 1890 (Boettger, 1890). This report (Boettger, 1890:LXIII) stated that Moellendorff brought in person a wonderful collection of Philippine species, which includes in particular the spectacular rarities from Leyte Island; a list of species followed. The text does not state unequivocably that all the listed species came from Leyte.

A comparison of the species purportedly from Leyte (Boettger, 1890), and the Senckenberg Museum catalogs (Boettger, 1893 and 1898) suggests that many of the specimens listed, including the single Z. luzonensis, are from other islands in the Philippines.

Leviton's casual, albeit correct, dismissal of the Leyte record for Z. luzonensis led him to conclude that this species is "evidently isolated on the northern islands of Luzon and Polillo" (1983:201). He apparently overlooked reports of Z. luzonensis on Negros Island (Brown and Alcala, 1961, 1964, 1970; Rabor et al., 1958, 1970).

The following records confirm the presence of Z. luzonensis in the western and central Visayan Islands. Its occurrence elsewhere in the Visayas is likely (Brown and Alcala, 1986) and cannot be casually dismissed.

NEGROS ISLAND: Negros Oriental Prov.: Valencia Municipality; Bong Bong Barrio, Camp Lookout, Maite Creek (ca. 16 km W of Dumaguete City). 22 September 1981. C. A. Ross. Verified by R.I. Crombie.

U.S. National Museum of Natural History, Smithsonian Institution (USNM 228404).

NEGROS ISLAND: Negros Oriental Prov.: Sibulan Municipality; Lake Balinsasayo. 16 October 1977. A.C. Alcala et al. Verified by R.I. Crombie. (USNM 269076). Same locality, 9 Novermber 1982 P. Heideman (head and posterior body only). Verified by R.I. Crombie. (USNM 269077). Same locality, January 1978. T. Batad. Verified by C.A. Ross. Natural History Museum, Silliman University, Dumaguete City, Philippines. (SU-R 1697).

PANAY ISLAND: Aklan Prov.: Libacao Municipality; Jamindang Barrio. 23 Februay 1987. R.V. Sison. Verified by R.I. Crombie. (USNM 269078).

All of these specimens have squamation typical of this species: a divided anal; 207 to 212 ventrals; 124 to 125 paired subcaudals; 8 supralabials with the 4th and 5th entering the orbit; and 14 or 12 smooth scale rows reducing to 12 or 11 anterior to the anus except the smallest (USNM 269078), a juvenile of 54 cm total length, with weakly keeled scale rows.

Field observations suggest that _Z. luzonensis_ is a secretive species found in areas of primary forest. The Negros Island specimens were taken in the immediate vicinity of water either on bushes overhanging a stream or lake, or in water.

We wish to thank R.I. Crombie and G.R. Zug for comments on drafts of this note and A. Elzanowski for verification of our translation of Boettger (1890).

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AN ANNOTATED CHECKLIST OF THE TAXONOMIC AND CONSERVATION STATUS OF LAND MAMMALS IN THE PHILIPPINES

Lawrence R. Heaney, Pedro C. Gonzales, and Angel C. Alcala

The mammal fauna of the Philippine Islands is currently considered to contain 165 species in the following orders (with number of species): Insectivora (10); Scandentia (2); Dermoptera (1); Chiroptera (69); Primates (3); Pholidota (1); Rodentia (66); Carnivora (7); Artiodactyla (6). We summarize information on the distribution, taxonomic, and conservatory status of each species, and provide a brief summary and bibliography of literature on Philippines mammals.

The Philippine Islands support a mammal fauna that i extemely rich in both diversity and number of endemics. Thi fauna has been the subject of taxonomic study for well over century, during which a gradual accretion of knowledge ha occurred. As this knowledge has accumulated, attempts have bee made to provide summaries of the fauna, in the form of eithe checklists or monographic reviews (Hollister, 1912, 1913; Taylor 1934; Alcasid, 1970). In the nearly twenty years that hav passed since the last such checklist was published, many ne species have been described, and revisions of various taxa hav resulted in changes in our perceptions of the taxonomic status c many species. However, these references are scattered i scientific journals published in many countries, and often ar not seen by non-specialists in mammalian taxonomy. Thus, ther is a need for a new summary of the Philippine mammal fauna; an this paper is intended to fill that need.

An additional need lies in the unhappy realization that th last eighteen years have seen a great reduction in the extent c forests in the Philippines, and a rising concern for the effect of deforestation on the unique mammal fauna of the country. recent paper has suggested that two species of fruit bats ar probably extinct (Heaney and Heideman, 1987), and several specie of large mammals are known to be severely threatened. In thi paper we have combined our personal knowledge of the mammals c the Philippines, obtained through many years of field work, t provide a brief assessment of the habitat requirements an conservation status of each species. These characterization should be taken as working hypotheses about the species rathe than as comprehensive, authoritative statements. The basi ecology of many species remains very poorly known, and man islands have never been surveyed; much field work will be neede before even these basic data are available. In many cases we ar unable to offer any comment; this should be taken as indicativ of the pressing need for additional field studies in the nea future.

Our comments on the distribution of each species are based on the published literature, our own field work, and specimens we have examined in collections. Because this paper is intended only as a working list of the mammals of the Philippines, we have not provided full taxonomic synonomies; earlier papers (Alcasid, 1969; Taylor, 1934) should be consulted for this information. We have used Honacki et al. (1982) as our starting point for both species names and for higher categories.

We have not included mention of subspecies designations in this list for two reasons. First, the use of subspecies names implies detailed knowledge of geographic variation, and such information is rarely available for Philippine mammals. Virtually all subspecies names now in use need to be reevaluated. Secondly, we believe that use of subspecies would distract the reader from more crucial issues of general distribution and conservation status.

The paper is divided in two sections. The first is a brief summary of the recent literature on Philippine mammals, and the second is the checklist itself.

RECENT LITERATURE ON PHILIPPINE MAMMALS

Although comprehensive description of the mammalian fauna of Southeast Asia began in the early 1800s, little was known of the mammalian fauna of the Philippines prior to the end of the nineteenth century. Since the publication of the first classic papers on the systematics and zoogeography of Philippine mammals (Everett, 1889; Steere, 1890; Thomas, 1898), information on the fauna has accumulated gradually. The first comprehensive summary, that of Hollister (1912, 1913), was based on a burst of field studies that occurred soon after the American occupation of the Philippines (Manuel, 1935). Interpretations of zoogeographic patterns were summarized in Dickerson (1928). Taylor's (1934) massive compilation, actually written in the mid-1920s, was also a product of this period. Lawrence (1939) contributed the first ecological data for many species, as well as many range records and descriptions of several new species. The post-World War II field studies described by Hoogstraal (1951), Sanborn (1952, 1953), and Rabor (1955) supplemented the earlier data, and left the impression that the fauna was, after 50 years of effort, moderately well known. However, in the 1980s a burst of descriptions of new species and of revisions showing that many taxa could not be distinguished (and thus were synonomized) has demonstrated that this was not so. This recent work has also shown that our past understanding of patterns of distribution was quite incomplete.

These historical patterns are easily recognized in Table 1, which shows the date of naming of each currently recognized species for each decade beginning in 1750. The non-endem species, those that occur elsewhere in Southeast Asia, we described from 1758 (the date of Linnaeus' first forma classification of organisms) to 1921, with a peak in the 1840s Very few of these were described from the Philippines, and ofte were not found there until much later. Although Linnaeus knew o two endemic Philippine species (the tarsier and flying lemur), n others were described until 1830, and description of endemi species did not peak until the first decade of this century Thereafter, there was a peak in the 1950s, but if the specie noted in this listing as probable subspecies are indeed found t be subspecies, this peak will diminish, leaving primarily the ca 14 species from the period of 1979 to the present a representatives of the post-1920 period of exploration.

Table 1. Numbers of species of mammals that occur in th Philippines described from 1758 to 1987 by ten-year intervals Species that are endemic to the Philippines are distinguishe from those that occur elsewhere.

	Endemic Species	Non-endemic Species
1750 - 1759	2	3
1760 - 1769	0	3
1770 - 1779	0	1
1780 - 1789	0	2
1790 - 1799	0	1
1800 - 1809	0	1
1810 - 1819	0	5
1820 - 1829	0	8
1830 - 1839	4	8
1840 - 1849	2	13
1850 - 1859	1	4
1860 - 1869	2	1
1870 - 1879	4	9
1880 - 1889	3	0
1890 - 1899	22	4
1900 - 1909	13	0
1910 - 1919	13	3
1920 - 1929	1	1
1930 - 1939	4	0
1940 - 1949	1	0
1950 - 1959	10	0
1960 - 1969	3	0
1970 - 1979	2	0
1980 - 1987	12	0

Recent publications on Philippine mammals fall into three general categories: systematic papers that deal with a single taxon, those that deal with all or many species from a single geographic region, and those that describe the ecology of one or more species. Taxonomic papers are listed in the text under each family; this listing is not comprehensive, in that we do not include papers concerning widespread species that occur in the Philippines when those papers do not make taxonomic changes.

Papers dealing with faunas, rather than specific taxa, include several that deal with the Philippines as a whole (Alcala, 1976; Groves 1984; Heaney 1985b, 1986; Rabor, 1977), and two that deal with important pre-1900 collections (Largen, 1985: Timm and Birney, 1982). Papers on mammals from Luzon include those by Catibog-Sinha (1982), and Mudar and Allen (1986); from the Semirara Islands near Mindoro (Alcala and Alviola, 1970); from Negros (Heaney et al, 1981; Rabor et al., 1970); from Palawan (Kuntz, 1969); from Mindanao (Sanguila and Tabaranza, 1979), and on small islands off Mindanao (Heaney and Rabor, 1982; Heaney, 1984; Tabaranza and Alconcel, 1979).

Ecological studies have treated the entire fauna (Alcala, 1976; Rabor, 1977); bats (Guerrero and Alcala, 1973; Heaney and Heideman, 1987; Heaney et al., 1981; Mudar and Allen, 1986; Tabaranza and Alconcel, 1979); shrews and rodents (Barbahenn et al., 1973; Heideman et al., 1987); tarsiers (McNab and Wright, 1987), small carnivores (Alcala and Brown, 1969); and ungulates (Cox, 1987; Kuehn, 1986).

A number of papers have discussed the need for conservation of Philippine mammals; general treatments include those by Gonzales and Alcala (1969), Rabor (1966a, 1968), and Tabaranza (1979). Papers dealing with individual species include those on deer and pigs (Cox, 1987), fruit bats (Heaney and Heideman, 1987), and dwarf water buffalo (Kuehn, 1986). The paper by Heaney and Heideman (1987) concludes that two species of fruit bats have become extinct in recent years, the first extinctions to be documented in the Philippines.

We also note that several papers have dealt with the fossil mammals of the Philippines. All of these species are Pleistocene in origin, all are large-bodied species, and all are poorly known (Fox and Peralta, 1974; Groves, 1984, 1985); additional work could add an exciting new dimension to our understanding of the evolution and ecology of the Philippine fauna.

CHECKLIST OF PHILIPPINE MAMMALS

By our count, there are 165 species of mammals known to occur in the Philippines. Of these, seven are introduced commensal species, 98 are endemic to the Philippines, and 60 are native to the Philippines and at least one other country.

In describing the distributions of species, we often refe to the zoogeographic regions of the country; these are shown i figure 1 (from Heaney, 1986). This map is based on the extent c islands in the Philippines during the late Pleistocene perio when the development of immense continental glaciers had, i effect, removed water form the world´s oceans, so that sea leve was 120 meters lower then it is today. Each of these "mega islands" defines the limit of a distinct fauna (Heaney, 1985 1986). The the three principal faunal regions thus defined ar the Luzon faunal region (including Luzon, Catanduanes Marinduque, and several small islands), the Mindanao fauna region (including Mindanao, Basilan, Bohol, Leyte, Samar, ar adjacent small islands), and the Palawan faunal region (includin Palawan, Balabac, Busuanga, Culion, Cuyo, and adjacent smal islands). Some other islands coalesced into islands larger tha those of today (e.g., a single island from Tawitawi to Jolo, an an island including Negros, Panay, Cebu, and Masbate), c remained isolated (e.g., Mindoro).

The recognition of these faunal regions is an important ai to understanding the distribution of Philippine mammals However, it should be borne in mind that many small islands hav never been surveyed, and many moderately large islands are poorl known. New distributional records are discovered by virtuall every regional survey, especially among the more poorly know taxa (such as bats). Further field work is essential t determine the distributions of many species, and to document th faunas of the smaller island groups.

INSECTIVORA

Erinaceidae - Hedgehogs and gymnures

A new species was described by Heaney and Morgan (1982) variation and distribution in P. truei was described by Poduschk and Poduschka (1985).

Podogymnura aureospinula Heaney and Morgan, 1982. Proc. Biol
Soc. Washington 95:14.
Distribution: Dinagat Island.
Status: Unknown; geographically restricted.

Podogymnura truei Mearns, 1905. Proc. U. S. Nat. Mus. 28:436
Distribution: Highlands of Mindanao.
Status: Probably widespread in high elevation forest on Mindanao

Soricidae - shrews

Heaney (in prep.) reported the first records of C. attenuat from the Philippines, reduced into synonomy C. palawanensis (wit C. fuliginosa), C. parvacauda (with C. beatus), and C. halconu

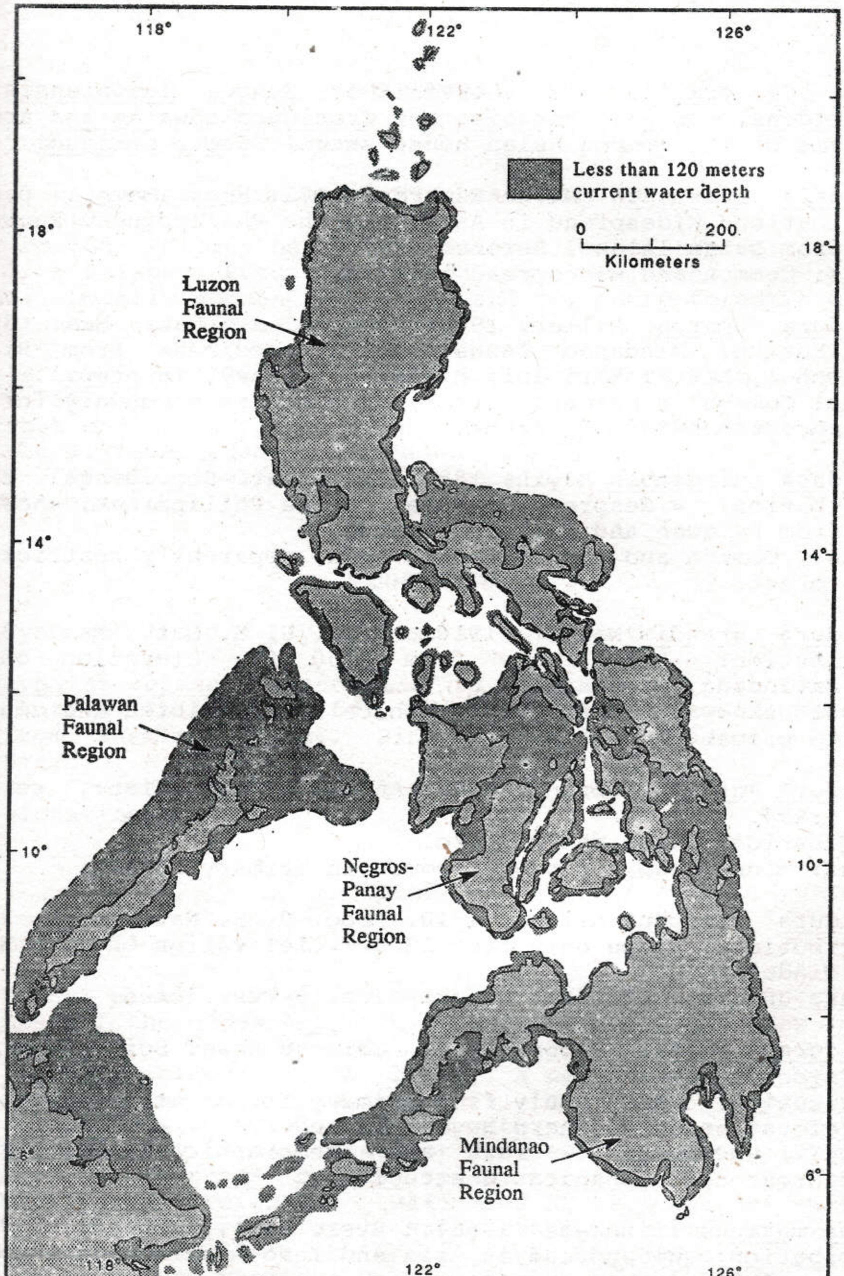

Fig. 1. Zoographic regions of the Philippines. Map is based on the extent of islands in the Philippines during the late Pleistocene period.

(with *C. grayi*), and showed that *Suncus luzoniensis*, *occultidens*, *S. palawanensis*, and *Crocidura edwardsiana* are synonyms of the common Asian house shrew, *Suncus murinus*.

Crocidura attenuata Milne-Edwards, 1872. Rech. Mamm., p. 26
Distribution: Widespread in Asia; in the Philippines, known on
from Batan Island, Batanes Prov.
Status: Common and widespread in Asia.

Crocidura beatus Miller, 1910. Proc. U. S. Nat. Mus. 38:39
Distribution: Mindanao faunal region; specimens from Bilira
Bohol, Leyte, Maripipi, Mindanao (Heaney, in prep.).
Status: Common in primary forest, uncommon in secondary forest,
absent outside of forest.

Crocidura fuliginosa Blyth, 1855. J. Asiat. Soc. Bengal 24:36
Distribution: Widespread in Asia; in the Philippines, known on
from Palawan and Balabac Islands.
Status: Common and widespread in Asia, apparently restricted
forest.

Crocidura grandis Miller, 1910. Proc. U. S. Nat. Mus. 38:39
Distribution: Known only from 6100 ft. elevation on M
Malindang, Mindanao.
Status: Unknown; probably geographically restricted and confine
to primary forest.

Crocidura grayi Dobson, 1890. Ann. Mag. Nat. Hist., ser. 6
6:494.
Distribution: Luzon and Mindoro.
Status: Widespread, probably common in primary forest.

Crocidura mindorus Miller, 1910. Proc. U. S. Nat. Mus. 38:39
Distribution: Known only from 6300 ft. elevation on Mt. Halco
Mindoro.
Status: Unknown; probably geographically restricted.

Crocidura negrina Rabor, 1952. Chicago Açad. Sci. Nat. His
Misc. 96:6.
Distribution: Known only from primary forest at 500 to 1450
elevation on southern Negros Island.
Status: uncommon or rare and geographically restricte
threatened by habitat destruciton.

Suncus murinus (Linnaeus, 1766). Syst. Nat., 12th ed., 1:74.
Distribution: Widespread in Asia and Indo-Australia; througho
the Philippines.
Status: Non-native; abundant in urban and agricultural area
often in disturbed forest, occasionally in primary forest.

SCANDENTIA

Tupaiidae - Tree Shrews

Tupaia palawanensis Thomas, 1894. Ann. Mag. Nat. Hist., ser. 6, 13:367.
Distribution: Philippines only; Palawan faunal region; specimens from Balabac, Busuanga, Culion, Cuyo, Palawan.
Status: Locally common in primary and secondary forest, coconut groves, and banana plantations.

Urogale everetti (Thomas, 1892). Ann. Mag. Nat. Hist., ser. 6, 9:250.
Distribution: Philippines only; highlands of Mindanao, Dinagat, and Siaragao (Heaney and Rabor, 1982).
Status: Probably widespread and locally abundant in forest on Mindanao.

DERMOPTERA

Cynocephalidae - Flying lemurs, colugos

Cynocephalus volans (Linnaeus, 1758). Syst. Nat., 10th ed., 1:30.
Distribution: Philippines only; Mindanao faunal region; specimens from Basilan, Bohol, Dinagat, Leyte, Mindanao, Samar, Siargao.
Status: Common in primary and secondary forest at low to middle elevations.

CHIROPTERA

Pteropodidae - Fruit bats

Musser et al. (1982) demonstrated that Pteropus leucotis is a member of the genus Acerodon. Description of two new genera and species, Alionycteris paucidentata and Otopteropus cartilagonodus (Kock, 1969b, 1969c), a new species of Nyctimene (N. rabori; Heaney and Peterson, 1984), and a new Ptenochirus (P. minor; Yoshiyuki, 1969), coupled with recognition of Dobsonia chapmani Rabor, 1952 as a distinct species (Bergmans, 1978), and synonomy of Pteropus balutus and P. tablasi with P. pumilus (Klingener and Creighton, 1984) and of P. mearnsi with P. speciosus (Heaney, in prep.), have greatly altered our view of the pteropodid fauna of the Philippines. Dyacopterus spadiceus was first reported from the Philippines by Kock (1969a).

Peterson and Fenton (1970) described variation in Harpyionycteris, and considered H. whiteheadi to be a separate species from H. celebensis. Examination of the holotypes of Cynopterus archipelagus and Macroglossus fructivorus has shown both to be juveniles that fall within the range of variation o *Cynopterus brachyotis* and *Macroglossus minimus*, respectivel (Heaney, pers. obs.).

Acerodon jubatus (Eschscholtz, 1831). Zool. Atl., Pt. 4:1.
Distribution: Philippines only; throughout the country with th exception of the Palawan faunal region.
Status: Widespread and locally common in primary forest; heavil hunted, declining.

Acerodon leucotis (Sanborn, 1950). Proc. Biol. Soc. Washingto 63:189.
Distribution: Palawan faunal region only; specimens from Balabac, Busuanga, Palawan.
Status: Uncertain, but probably moderately common in forest.

Acerodon lucifer Elliot, 1896. Field. Columbian Mus. Publ., Zool. Ser., 1:78.
Distribution: Panay only.
Status: Not seen since 1888; presumed extinct.

Alionycteris paucidentata Kock, 1969. Senckenberg. Bio. 50:319.
Distribution: Known only from Mt. Katanglad, Bukidnon Prov., Mindanao.
Status: Probably uncommon and geographically restricted.

Cynopterus brachyotis (Muller, 1838). Tijdschr. Nat. Gesch. Physiol. 5:146.
Distribution: Throughout the Philippines; widespread in Southeas Asia.
Status: Abundant in agricultural areas, less common in forest.

Dobsonia chapmani Rabor, 1952. Chicago Acad. Sci. Nat. Hist. Misc. 96:2.
Distribution: Known only from Negros and Cebu.
Status: Last seen in 1964; probably extinct due to habitat destruction and hunting (Heaney and Heideman, 1987).

Dyacopterus spadiceus (Thomas, 1890). Ann. Mag. Nat. Hist., ser. 6, 5:235.
Distribution: Sumatra and the Malay Peninsula to the Philippines; specimens only from Luzon and Mindanao.
Status: Unknown; widespread but rare in museum collections.

Eonycteris robusta Miller, 1913. Proc. Biol. Soc. Washingto 26:73
Distribution: Philippines only; specimens from Leyte, Luzon, Mindanao, Negros, Siargao.
Status: Widespread in primary forest but not common; apparentl rare or absent outside of forest. Taxonomic statu uncertain; sometimes considered a subspecies of *E. majo*

(Honacki et al., 1982), but there is no evidence of intergradation between the Bornean and Philippine morphotypes (Heaney, unpub. data), so we retain the species.

Eonycteris spelaea (Dobson, 1871). Proc. Asiatic Soc. Bengal, p. 105, 106.
Distribution: India to Timor; throughout the Philippines.
Status: Common, especially in agricultural areas; heavily hunted.

Haplonycteris fischeri Lawrence, 1939. Bull. Mus. Comp. Zool., 86:33
Distribution: Philippines only; throughout the country, possibly excluding the Palawan faunal region.
Status: Common in primary forest, rare in secondary forest, absent outside of forest.

Harpyionycteris whiteheadi Thomas, 1896. Ann. Mag. Nat. Hist., ser. 6, 18:244.
Distribution: Philippines only; Mindanao faunal region, Negros, Mindoro.
Status: Locally common to uncommon in moderate to high elevation primary rain forest, absent elsewhere.

Macroglossus minimus (E. Goeffroy, 1810). Ann. Mus. Hist. Nat. Paris, 15:97.
Distribution: Thailand to Australia, throughout the Philippines.
Status: Abundant, expecially in agricultural areas.
Megaerops wetmorei Taylor, 1934. Monogr. Bur. Sci. Manila, 30:191.
Distribution: Mindanao only (but reported without documentation from Borneo by Payne et al., 1985).
Status: Unknown; geographically restricted and probably confined to primary forest.

Nyctimene rabori Heaney and Peterson, 1984. Occ. Pap. Mus. Zool. Univ. Michigan 708:3.
Distribution: Known only from southern Negros Island.
Status: Rare and geographically restricted, in primary forest only, declining due to habitat destruction.

Otopteropus cartilagonodus Kock, 1969. Senckenberg. Biol. 50:333.
Distribution: Luzon only.
Status: Poorly known, apparently locally common in primary and good secondary forest, probably absent outside of forest.

Ptenochirus jagori. (Peters, 1861). Monatsb. Preuss. Akad. Wiss. Berlin, p. 707.
Distribution: Philippines only; throughout the country, excluding the Palawan region.
Status: Abundant in primary forest, less common in secondary forest, occasionally in agricultural areas near forest.

Ptenochirus minor Yoshiyuki, 1979. Bull. Nat. Sci. Mus. Tokyo, ser. A (Zool.), 5:75.
Distribution: Mindanao faunal region only; specimens from Biliran, Dinagat, Leyte, Mindanao; possible record from Palawan.
Status: Abundant in primary forest, uncommon in secondary forest, absent outside of forest.

Pteropus hypomelanus Temminck, 1853. Esquisses, Zool. sur la Cote de Guine, p. 61.
Distribution: Thailand to Australia; throughout the Philippines, possibly excluding the Palawan region.
Status: Common in agricultural areas; hunted, locally uncommon.

Pteropus leucopterus Temminck, 1853. Esquisses, Zool. sur la Cote de Guine, p. 60.
Distribution: Known only from Luzon and Dinagat.
Status: Probably rare: may be cloud forest endemic.

Pteropus pumilus Miller, 1910. Proc. U. S. Nat. Mus. 38:394.
Distribution: Philippines only; throughout the Philippines, excluding the Palawan faunal region.
Status: Locally common to uncommon in primary forest, uncommon in secondary forest, rare or absent outside of forest.

Pteropus speciosus Andersen, 1908. Ann. Mag. Nat. Hist., ser. 8, 2:364.
Distribution: Mindanao, Basilan, and Sulu Archipelago only.
Status: Unknown; geographically restricted, uncommon in collections.

Pteropus vampyrus (Linnaeus, 1758). Syst. Nat., 10th ed., 1:31.
Distribution: Indochina to Lesser Sunda Islands; throughout the Philippines.
Status: Widespread and locally common in primary forest; heavily hunted, declining.

Rousettus amplexicaudatus (E. Geoffroy, 1810). Ann. Mus. Hist. Nat. Paris 15:96.
Distribution: Thailand to Solomon Islands; throughout the Philippines.
Status: Abundant, especially in agricultural areas; heavily hunted.

Emballonuridae - Sheath-tailed bats

Emballonura alecto (Eydoux and Gervais, 1836). Mag. Zool., Paris, 6:7.
Distribution: Borneo, Philippines, Sulawesi; throughout the Philippines.

Status: Common in areas with caves in or near forest; apparently rare eleswhere.

Saccolaimus pluto (Miller, 1910). Proc. U. S. Nat. Mus. 38:396.
Distribution: Philippines only, but may be a subspecies of widespread *S. saccolaimus*.
Status: Poorly known; may be moderately common in agricultural areas.

Taphozous philippinensis Waterhouse, 1845. Proc. Zool. Soc. London 1845:9.
Distribution: Philippines only, but may be a subspecies of widespread *T. melanopogon.*
Status: Common in urban areas and in areas with caves.

Megadermatidae - False vampire bats

Megaderma spasma (Linnaeus, 1758). Syst. Nat., 10th ed., 1:32.
Distribution: India to the Molucca Islands; throughout the Philippines.
Status: Locally common to uncommon in primary forest and secondary forest.

Rhinolophidae - Horseshoe and roundleaf bats

This family is very poorly known, principally because they are difficult to capture; new records and major changes in known distributions are to be expected.

Hill (1963) included *Hipposideros wrighti* Taylor, 1934 as a synonym of *H. ater*, a species which formerly had been considered a synonym of *H. bicolor*. Jenkins and Hill (1981) assigned records previously reported as *H. galeritus* to *H. cervinus*.

Coelops hirsuta (Miller, 1911). Proc. U. S. Nat. Mus. 38:395.
Distribution: Mindoro only, but may be a subspecies of *C. robinsoni*, known from the Malay Peninsula and Borneo.
Status: Unknown; may be dependent on caves.

Hipposideros ater Templeton, 1848. J. Asiatic Soc. Bengal, 17:252.
Distribution: India to Australia; throughout the Philippines.
Status: Unknown.

Hipposideros bicolor (Temminck, 1834). Tijdschr. Nat. Gesch. Physiol., 1:19.
Distribution: India to Timor; Philippine specimens from Luzon, Mindoro, Palawan.
Status: Unknown.

Hipposideros cervinus (Tomes, 1859).
Distribution: Peninsular Malaysia to New Guinea; Philippi
specimens from Mindanao only.
Status: Unknown.

Hipposideros coronatus (Peters, 1871). Monatsb. Preuss. Aka
Wiss. Berlin, p. 327.
Distribution: Known only from Mainit, Surigao Prov. Mindanao.
Status: Unknown; geographically restricted.

Hipposideros diadema (E. Geoffroy, 1813). Ann. Mus. Hist. Na
Paris 20:263.
Distribution: Burma to the Solomon Islands; throughout th
Philippines.
Status: Widespread and common.

Hipposideros obscurus (Peters, 1861). Monatsb. Preuss. Akad
Wiss. Berlin, p. 707.
Distribution: Philippines only; specimens from Dinagat, Luzon
Mindanao.
Status: Widespread, locally common to uncommon in primary forest

Hipposideros pygmaeus (Waterhouse, 1843). Proc. Zool. Soc. Londo
1843: 67.
Distribution: Philippines only; specimens from Bohol, Luzon
Negros.
Status: Widespread, apparently restricted to caves in foreste
areas.

Rhinolophus acuminatus Peters, 1871. Montasb. Preuss. Akad. Wiss
Berlin, p. 308.
Distribution: Thailand to Lombok; in Philippines, known only fro
Palawan faunal region.
Status: Uncertain; apparently locally common.

Rhinolophus anderseni Cabrera, 1909. Bol. Soc. Esp. Nat. Hist.
p. 305.
Distribution: Philippines only; records from Luzon and Palawan.
Status: Unknown; rare in collections.

Rhinolophus arcuatus Peters, 1871. Monatsb. Preuss. Aka. Wiss
Berlin p. 305.
Distribution: Sumatra to New Guinea; throughout the Philippines
possibly excluding the Palawan faunal region.
Status: Widespread, locally common in caves.

Rhinolophus inops Andersen, 1905. Ann. Mag. Nat. Hist., ser. 7
16:284, 651.
Distribution: Philippines only; specimens from Mindanao fauna
region only.
Status: Locally abundant in primary forest.

inolophus macrotis Blyth, 1844. J. Asiat. Soc. Bengal. 13:485.
stribution: India to Sumatra and the Philippines.
atus: Widespread but uncommon, primary forest only.

inolophus philippinensis Waterhouse, 1843. Proc. Zool. Soc. London 1843:68.
stribution: Borneo and the Philippines to Australia; Philippine records from Luzon, Mindanao, Mindoro, Negros.
atus: Uncertain; apparently uncommon, primary forest only.

inolophus rufus Eydoux and Gervais, 1836. Zool. Voy. "Favorite", p. 9.
stribution: Philippines only; specimens from Bohol, Luzon, Mindanao, Mindoro.
atus: Uncertain; locally common in caves in forest.

inolophus subrufus Andersen, 1905. Ann. Mag. Nat. Hist., ser. 7, 16:283.
stribution: Philippines only; specimens from Luzon, Mindanao, Mindoro.
atus: Unknown; the few available specimens were taken in caves.

inolophus virgo Andersen, 1905. Proc. Zool. Soc. London, 1905:88.
stribution: Philippines only; throughout the Philippines.
atus: Widespread and common.

Vespertilionidae - Common bats

We follow Hill (1983) in considering Miniopterus australis to include paulutus, and M. schreibersii to include eschscholtzii; however, we recognize that this is provisional and in need of further study. Peterson (1981) commented on variation in Miniopterus tristis.

Findley (1972) considered Myotis rufopictus to be a subspecies of M. formosus. Hill (1983) listed Myotis jeannei as a subspecies of M. horsfieldii, and M. browni and M. herrei as synonyms of Myotis muricola. Honacki et al. (1982) considered M. patriciae to be a synonym of M. muricola, and Heaney's examination (unpubl. obs.) of the holotype confirms this. Philetor brachypterus was first reported from the Philippines by Rock (1981). Pipistrellus javanicus is considered to include P. tramus and P. irretitus (Honacki et al., 1982). Previously unreported specimens of Pipistrellus petersi from Luzon and Mindanao are housed in the US National Museum and the American Museum of Natural History. Tylonycteris robustula was first reported from the Philippines by Heaney and Alcala (1986).

Kerivoula? ischropus tylopus Dobson, 1875. Proc. Zool. Soc. London 1875:473.

Distribution: Burma to Molucca Islands; Philippine records from Palawan only.
Status: Unknown.

Kerivoula hardwickii (Horsfield, 1824). Zool. Res. Java, Pt. 8:28.
Distribution: India and southern China to Lesser Sunda Islands; Philippine records from Mindanao, Palawan, Samar.
Status: Uncertain; probably moderately common in primary forest.

Kerivoula pellucida (Waterhouse, 1845). Proc. Zool. Soc. London, 1845:6.
Distribution: Borneo, Java, Malay Peninsula, Sumatra, Mindanao, Jolo, Palawan.
Status: Unknown.

Kerivoula whiteheadi Thomas, 1894. Ann. Mag. Nat. Hist., ser. 6, 14:460.
Distribution: Southern Thailand to Borneo, Philippines; records from Luzon, Mindanao, and Panay.
Status: Unknown.

Miniopterus australis Tomes, 1858. Proc. Zool. Soc. London 1858:125.
Distribution: India to Australia; throughout the Philipines.
Status: Common, dependent on caves.

Miniopterus schreibersii (Kuhl, 1819). Ann. Wetterau Ges. Naturk. 4(2):185.
Distribution: Europe to Solomon Islands; throughout the Philippines.
Status: Common, dependent on caves.

Miniopterus tristis (Waterhouse, 1845). Proc. Zool. Soc. London, 1845:3.
Distribution: Philippines to Solomon Islands; records throughout the Philippines, possibly excluding Palawan faunal region.
Status: Common, dependent on caves.

Murina cyclotis Dobson, 1872. Proc. Asiat. Soc. Bengal, p. 210.
Distribution: Sri Lanka to Hainan and Borneo, Philippines; records from Luzon and Mindanao only.
Status: Unknown.

Myotis formosus (Hodgson, 1835). J. Asiat. Soc. Bengal 4:700.
Distribution: Afghanistan to Philippines and Sulawesi. Philippine populations may be a distinct species, *M. rufopictus*.
Status: Unknown; rare in museum collections.

Myotis horsfieldii (Temminck, 1840). Monogr. Mamm. 2:226.

Distribution: SE China to Malay Peninsula, Bali, and Sulawesi; Philippine records from Luzon, Mindanao, Negros, and Palawan.
Status: Moderately common in caves and primary forest.

Myotis macrotarsus (Waterhouse, 1845). Proc. Zool. Soc. London 1845:5.
Distribution: Borneo and the Philippines; throughout the Philippines.
Status: Widespread but uncommon, dependent on caves.

Myotis muricola (Gray, 1846). Cat. Hodgson Coll. Brit. Mus., p. 4.
Distribution: Afghanistan to New Guinea; throughout the Philippines.
Status: Widespread, moderately common in agricultural and forested areas.

Philetor brachypterus (Temminck, 1840). Monogr. Mamm., 2:215.
Distribution: Sumatra to New Guinea; Philippine records from Mindanao and Negros.
Status: Uncertain; probably moderately common in primary forest.

Phoniscus jagorii (Peters, 1866). Monatsb. Preuss. Akad. Wiss. Berlin, p. 399.
Distribution: Bali, Borneo, Java, Sulawesi, and Samar.
Status: Unknown.

Pipistrellus javanicus (Gray, 1838). Mag. Zool. Bot. 2:498.
Distribution: Korea to Java and the Philippines; throughout the Philippines.
Status: Moderately common in primary and secondary forest.

Pipistrellus petersi (Meyer, 1899). Abh. Zool. Anthrop.-Ethnology. Mus. Dresden 7(7):13.
Distribution: Sulawesi, Molucca Islands, and the Philippines; records from Luzon and Mindanao.
Status: Unknown.

Pipistrellus stenopterus (Dobson, 1875). Proc. Zool. Soc. London 1875:470.
Distribution: Sumatra to Mindanao; a single Philippine specimen from Zamboanga, Mindanao.
Status: Unknown.

Pipistrellus tenuis (Temminck, 1840). Monogr. Mamm., 2:229.
Distribution: Thailand to Australia; records from Mindanao and Negros.
Status: Moderately common in primary forest.

Scotophilus kuhlii Leach, 1822. Trans. Linn. Soc. London, 13:71
Distribution: Pakistan to Taiwan and Bali; throughout the Philippines.
Status: Abundant in urban and agricultural areas.

Tylonycteris pachypus (Temminck, 1840). Monogr. Mamm. 2:217.
Distribution: India to Philippines and Lesser Sunda Islands; throughout the Philippines.
Status: Probably moderately common.

Tylonycteris robustula Thomas, 1915. Ann. Mag. Nat. Hist., ser. 8, 15:227.
Distribution: Southern China to Lesser Sunda Islands; Philippine records from Luzon and Calauit only.
Status: Unknown.

Molossidae - Free-tailed bats

Freeman (1981) recognized Chaerophon, formerly a subgenus of Tadarida, as a valid genus; Hill (1961) had previously placed T. luzonus as a synonym of C. plicata. Freeman (1981) also listed Philippinopterus as a synonym of Mops, and lanei as a subspecies of Mops sarasinorum.

Chaerophon plicata (Buchanon, 1800). Trans. Linn. Soc. London 5:261.
Distribution: India to Bali and Hainan; Philippine records from Cebu, Leyte, Luzon, Mindanao, Negros.
Status: Unknown; probably represented by a few very large colonies in caves.

Cheiromeles parvidens Miller and Hollister, 1921. Proc. Biol. Soc. Washington 34:100.
Distribution: Sulawesi, Mindanao, Mindoro, and Negros.
Status: Unknown.

Cheiromeles torquatus Horsfield, 1824. Zool. Res. Java, Pt. 8.
Distribution: Sumatra to Java and Palawan; Philippine records from Palawan only.
Status: Unknown.

Mops sarasinorum (Meyer, 1899). Abh. Zool. Anthrop. Ethnology. Mus. Dresden 7(7):15.
Distribution: Sulawesi and Philippines; records from Mindanao only.
Status: Unknown.

PRIMATES

Lorisidae - Lirises and coucangs

Nycticebus coucang Boddaert, 1785. Elench. Anim., p. 67.
Distribution: India to Borneo and Philippines: records from Sulu Archipelago only (Musser and Heaney, 1985.
Status : Unknown.

Tarsiidae - Tarsiers

The taxonomic status of the four species of Tarsius was reviewed by Musser and Dagosto (1987).

Tarsius syrichta (Linnaeus, 1758). Syst, Nat., 10th ed., 1:29.
Distribution: Philippines only; records from Basilan, Biliran, Bohol, Dinagat, Leyte, Mindanao, and Samar.
Status: Locally common in low to mid-elevation primary and secondary forest and secondary growth in agricultural areas.

Cercopithecidae - Monkeys

Macaca fascicularis (Raffles, 1821). Trans. Linn. Soc. London 13:246.
Distribution: Burma to Timor; throughout the Philippines.
Status: Locally common to uncommon; hunted heavily.

PHOLIDOTA

Manidae - pangolins

Manis javanica Desmarest, 1822. Encyclop. Method. Mamm. 2:377.
Distribution: Burma to Java, Philippines; Philippine records from Palawan faunal region only.
Status: Uncommon, heavily hunted; possibly seriously endangered.

RODENTIA

Sciuridae - Squirrels

Heaney (1985a) considered Exilisciurus to be a valid genus, but considered E. luncefordi, E. samaricus, and E. surrutilus to be synonyms of E. concinnus. Heaney (1979) described a new tree squirrel, Sundasciurus rabori, from Palawan.

Exilisciurus concinnus (Thomas, 1888). Ann. Mag. Nat. Hist., ser. 6, 6:407.

Distribution: Philippines only; records from Mindanao faunal region.
Status: Widespread, moderately common at upper elevations in primary and secondary forest, absent outside of forest.

Hylopetes mindanensis (Rabor, 1939). Philippine J. Sci. 69:389.
Distribution: Known only from Gingoog, Misamis Oriental Prov., Mindanao.
Status: Unknown; holotype destroyed during WW II; possibly allied to Petinomys crinitus.

Hylopetes nigripes Thomas, 1893. Ann. Mag. Nat. Hist., ser. 6, 12:30.
Distribution: Palawan Island only.
Status: Moderately common.

Petinomys crinitus Hollister, 1911. Proc. Biol. Soc. Washington 24:185.
Distribution: Philippines only; records from Basilan, Dinagat, Mindanao, and Siargao.
Status: Uncertain; probably moderately common in primary forest.

Sundasciurus davensis (Sanborn, 1952). Fieldiana Zool. 33:117.
Distribution: Known only from Davao Prov., Mindanao; probably a subspecies of S. philippinensis.
Status: Uncertain; probably locally common.

Sundasciurus hoogstraali (Sanborn, 1952). Fieldiana, Zool. 33:115.
Distribution: Busuanga Island only.
Status: Locally common.

Sundasciurus juvencus (Thomas, 1908). Ann. Mag. Nat. Hist., ser. 8, 2:498.
Distribution: Central (north of Abo-abo) and northern Palawan Island only.
Status: Locally common.

Sundasciurus mindanensis (Steere, 1890). List of the Birds and Mammals collected by the Steere Expedition to the Philippines, p. 29.
Distribution: Philippines only; Mindanao and adjacent small islands; probably a subspecies of S. philippinensis.
Status: Locally abundant in secondary and primary forest.

Sundasciurus mollendorffi (Matschie, 1898). Sitzb. Ges. Naturf. Fr. Berlin 5:41
Distribution: Culion, Linapacan, Iloc, and Tampel Islands only.
Status: Locally abundant in primary and secondary forest and coconut groves. Currently includes S. albicauda Matschie, 1898, but further study is needed.

Sundasciurus philippinensis (Waterhouse, 1839). Proc. Zool Soc. London 1839:117.
Distribution: Philippines only; Mindanao and adjacent islands.
Status: Locally common in forested regions.

Sundasciurus rabori Heaney, 1979. Proc. Biol. Soc. Washington 92:281.
Distribution: Known only from vicinity of Mt. Mantalingajan, Palawan Island.
Status: Geographically restricted, probably confined to upper elevation forest; moderately common.

Sundasciurus samarensis Steere, 1890. List of the Birds and Mammals collected by the Steere Expedition to the Philippines, p.30.
Distribution: Bohol, Leyte, Samar, and adjacent islands; may be a subspecies of S. philippinensis.
Status: Common in primary and secondary forest.

Sundasciurus steeri (Gunther, 1877). Proc. Zool. Soc. London 1876:735.
Distribution: Balabac and southern Palawan (Brooke´s Point Municipality) Islands only.
Status: Common in lowland forest, coconut groves, and banana plantations.

Muridae - Mice and rats

The murids have been more extensively studied in recent years than any other group of Philippine mammals. Five new genera have been described (Abditomys Musser, 1982a; Anonymomys Musser, 1981; Archboldomys Musser, 1982c; Palawanomys Musser and Newcomb, 1983; Sundamys Musser and Newcomb, 1983), and five genera that at times have been listed as subgenera of Rattus are now recognized as valid (Apomys, by Musser, 1982b; Bullimus, by Musser, 1982c; Limnomys, by Musser, 1977b; Maxomys, by Musser et al., 1979; and Tryphomys, by Musser, 1981b). Mindanaomys is now considered to be a synonym of Batomys (Musser, 1981b). New species have been named in the genera Batomys (Musser and Heaney, in prep.), Crateromys (Musser and Gordon, 1981; Musser et al., 1985), Crunomys (Musser, 1982c), Haeromys (Musser, in prep.), Rattus (Musser and Heaney, 1985), and Rhynchomys (Musser and Freeman, 1981). Study of geographic variation in Chrotomys indicates that two species are present (Musser et al., 1981). The validity of Chiropodomys calamianensis has been confirmed (Musser, 1979). All Philippine populations of Mus are now placed in the species M. musculus (subspecies castaneus), and the species is considered to be non-native (Marshall, 1977; Marshall and Sage, 1981; Marshall, 1986). Many populations formerly recognized as species of Rattus are now considered to be synonyms of Rattus exulans, R. norvegicus, and R. rattus (Musser, 1977).

Abditomys latidens (Sanborn, 1952). Fieldiana Zool. 33:125.
Distribution: Known only from Mountain and Laguna provs., Luzon.
Status: Uncertain; probably uncommon.

Anonymomys mindorensis Musser, 1981. Bull. Amer. Mus. Nat. Hist. 168:300.
Distribution: Known only from Ilong Peak, Halcon Range, Mindoro.
Status: Unknown; geographically restricted, rare in collections.

Apomys abrae (Sanborn, 1952). Fieldiana Zool. 33:133.
Distribution: Known only from the central cordillera of Luzon.
Status: Uncertain; probably widespread in middle to high elevation forest in northern Luzon.

Apomys datae (Meyer, 1899). Abhand. Mus. Dresden, ser. 7, 7:25.
Distribution: Known only from Mountain Prov., Luzon.
Status: Uncertain, known only from high elevation forest, geographically restricted.

Apomys hylocetes Mearns, 1905. Proc. U.S. Nat. Mus. 28:456.
Distribution: Known only from high elevations on Mt. Apo, Davao Prov., Mindanao.
Status: Unknown; uncommon in museum collections.

Apomys insignis Mearns, 1905. Proc. U.S. Nat. Mus. 28:459.
Distribution: Widespread in Mindanao.
Status: Probably common in forest at middle to high elevations, especially in mossy forest.

Apomys littoralis (Sanborn, 1952). Fieldiana Zool. 33:134.
Distribution: Known only from the coastal plain of Cotabato Prov., Mindanao and the highlands of southern Negros Island.
Status: Locally common in primary forest on Negros Island; absent outside of forest.

Apomys microdon Hollister, 1931. Proc. U.S. Nat. Mus. 46:327.
Distribution: Recorded from Catanduanes, Leyte, and Dinagat.
Status: Common in primary forest at middle to high elevations, rare in secondary forest.

Apomys musculus Miller, 1911. Proc. U.S. Nat. Mus. 38:403.
Distribution: Highlands of Luzon and Mindoro.
Status: Widespread in forest at middle to high elevations, but apparently uncommon.

Apomys sacobianus Johnson, 1962. Proc. Biol. Soc. Washington 75:319.

Distribution: Known only from the lowlands of Pampanga Prov., Luzon.
Status: Unknown; rare in museum collections.

Archboldomys luzonensis Musser, 1982. Bull. Amer. Mus. Nat. Hist. 174:30.
Distribution: Known only from Mt. Isarog, Camarines Sur Prov., Luzon.
Status: Unknown; rare in museum collections.

Batomys dentatus Miller, 1910.Proc. U.S. Nat. Mus. 38:400.
Distribution: Known only from Benguet Prov., Luzon.
Status: Unknown; rare in museum collections.

Batomys granti Thomas, 1895. Ann. Mag. Nat. Hist., ser. 6, 16:162.
Distribution: Known only from Mt. Data, Benguet Prov., Luzon.
Status: Unknown; rare in museum collections.

Batomys salomonseni (Sanborn, 1953). Vidensk. Medd. Dan. Naturhist. Foren. 115:287.
Distribution: Mindanao faunal region; records from Biliran, Leyte, and Mindanao.
Status: Common in primary forest at high elevations.

Batomys sp.
Distribution: Known only from Dinagat Island; see Heaney and Rabor, 1982.
Status: Unknown: geographically restricted.
Bullimus bagobus Mearns, 1905. Proc. U.S. Nat. Mus. 28:450.
Distribution: Widespread in Mindanao faunal region.
Status: Common in low and mid-elevation primary forest.

Bullimus luzonicus (Thomas, 1895). Ann. Mag. Nat. Hist., ser. 6, 16:163.
Distribution: Highlands of northern Luzon.
Status: Probably common in primary forest.

Bullimus rabori (Sanborn, 1952). Fieldiana Zool. 33:130.
Distribution: Zamboanga Peninsula, Mindanao; may be a subspecies of B. bagobus.
Status: Probably common.

Carpomys melanurus Thomas, 1895. Ann. Mag. Nat. Hist., ser. 6, 16:162.
Distribution: Known only from Benguet Prov., Luzon.
Status: Unknown; rare in museum collections.

Carpomys phaeurus Thomas, 1895. Ann. Mag. Nat. Hist., ser. 6, 16:162.
Distribution: Known only from Benguet and Ifugao provs., Luzon.

Status: Unknown; rare in museum collections.

Celaenomys silaceus (Thomas, 1895). Ann. Mag. Nat. Hist., ser. 6, 16:161.
Distribution: Known only from high elevation forest in Benguet Prov., Luzon.
Status: Unknown; uncommon in museum collections.

Chiropodomys calamianensis (Taylor, 1934). Monogr. Bur. Sci. Manila 30:470.
Distribution: Palawan faunal region only; records from Balabac, Busuanga, and Palawan islands.
Status: Unknown; uncommon in museum collections.

Chrotomys mindorensis Kellogg, 1945. Proc. Biol. Soc. Washington 58:123.
Distribution: Mindoro and lowland central Luzon.
Status: Widespread, apparently not common.

Chrotomys whiteheadi Thomas, 1895. Ann. Mag. Nat. Hist., ser. 6, 16:161.
Distribution: Known only from Benguet Prov., Luzon.
Status: Unknown; uncommon in museum collections.

Crateromys australis Musser, Heaney, and Rabor, 1985. Amer. Mus. Novitates 2821:3.
Distribution: Known only from Dinagat Island.
Status: Unknown; geographically restricted, very rare in museum collections.

Crateromys paulus Musser and Gordon, 1981. J. Mammal. 62:515.
Distribution: Known only from Ilin Island, south of Mindoro.
Status: Unknown; geographically extremely restricted, rare in museum collections.

Crateromys schadenbergi (Meyer, 1895). Abhand. Mus. Dresden 6:1.
Distribution: Known only from Benguet and Ifugao provs., Luzon.
Status: Uncertain; apparently locally common in oak-pine forest, rare elsewhere; hunted.

Crunomys fallax Thomas, 1897. Trans. Zool. Soc. London 14(6):394.
Distribution: Known only from Isabela Prov., Luzon.
Status: Unknown; rare in collections.

Crunomys melanius Thomas, 1907. Proc. Zool. Soc. London 1907:141.
Distribution: Known only from southern Mindanao.
Status: Unknown; rare in museum collections.

Crunomys rabori Musser, 1982. Bull. Amer. Mus. Nat. Hist. 174:14.
Distribution: Known only from the highlands of northern Leyte.
Status: Uncertain; rare in museum collections, probably confined to mossy forest.

Haeromys sp.
Distribution: Known only from Palawan and Calauit Islands, Palawan faunal region (see Musser 1983).
Status: Unknown; rare in museum collections.

Limnomys sibuanus Mearns, 1905. Proc. U.S. Nat. Mus. 28:452.
Distribution: Known only from Mts. Apo and Malindang, southern Mindanao.
Status: Unknown; rare in museum collections.

Maxomys panglima (Robinson, 1921). Ann. Mag. Nat. Hist., ser. 9, 7:235.
Distribution: Palawan faunal region only.
Status: Common in secondary and primary forest from lowlands to high elevations.

Mus musculus Waterhouse, 1843. Ann. Mag. Nat. Hist. 12:134
Distribution: Widespread in SE Asia.
Status: Non-native; abundant in urban areas.

Palawanomys furyus Musser and Newcomb, 1983. Bull. Amer. Mus. Nat. Hist. 174:335.
Distribution: Known only from Mt. Mantalingajan, Palawan Island.
Status: Unknown; rare in museum collections.

Phloemys cumingi Waterhourse, 1839. Proc. Zool. Soc. London 1839:108.
Distribution: Southern Luzon.
Status: Uncertain.

Phloemys pallidus Nehring, 1890. Sitzb. Ges. Naturf. Fr. Berlin, p.106.
Distribution: Highlands of northern Luzon.
Status: Widespread and apparently common in forests; hunted.

Rattus argentiventer (Robinson and Kloss, 1916). J. Straits Br. Roy. Asiat. Soc. 73:274.
Distribution: Thailand to New Guinea; known only from Luzon, Mindanao, and Mindoro in the Philippines.
Status: Non-native; probably locally abundant in agricultural areas.

Rattus everetti (Gunther, 1879). Proc. Zool. Soc. London 1879:75.
Distribution: Widespread in the Philippines excluding Palawan faunal region.

Status: Common in primary forest, uncommon in secondary forest; absent outside of forest.

Rattus exulans (Peale, 1848). Mammalia and Ornithology, in U.S. Expl. Exped. 8:47.
Distribution: Bangladesh to Easter Island; throughout the Philippines.
Status: Non-native; abundant in agricultural areas, usually rare in forest.

Rattus mindorensis (Thomas, 1898). Trans. Zool. Soc. London 14:402.
Distribution: Known only from Mindoro Island.
Status: Common at high elevations.

Rattus nitidus (Hodgson, 1845). Ann. Mag. Nat. Hist. 15:267.
Distribution: Nepal to New Guinea; in the Philippines, known only from Benguet Prov., Luzon.
Status: Non-native; probably locally abundant in highland agricultural areas.

Rattus norvegicus (Berkenhout, 1769). Outlines Nat. Hist. Great Britain and Ireland 1:5 (N. V.).
Distribution: Worldwide.
Status: Non-native; abundant in urban areas.

Rattus rattus (Linnaeus, 1758). Syst, Nat., 10th ed., 1:61.
Distribution: Worldwide.
Status: Non-native; abundant in urban and agricultural areas; common in disturbed forest.

Rattus tiomanicus (Miller, 1910). Proc. Washington Acad. Sci. 2:212.
Distribution: Malay Peninsula to Borneo and Palawan; in Philippines, in Palawan region only.
Status: Abundant in agricultural areas.

Rattus tawitawiensis Musser and Heaney, 1985. Amer. Mus. Novitates 2818:5.
Distribution: Known only from Tawitawi Island, Sulu Archipelago.
Status: Uncertain; geographically restricted, probably threatened by habitat destruction.

Rattus tyrannus (Miller, 1910). Proc. U.S. Nat. Mus. 38:397.
Distribution: Ticao Island only; probably a subspecies of R. everetti.
Status: Unknown.

Rhynchomys isarogensis Musser and Freeman, 1981. J. Mammal. 62:154.

Distribution: Known only from Mt. Isarog, Camarines Sur Prov., Luzon.
Status: Uncertain; geographically restricted, rare in museum collections.

Rhynchomys soricoides Thomas, 1895. Ann. Mag. Nat. Hist., ser. 6, 16:160.
Distribution: Known only from Mt. Data, Benguet Prov., Luzon.
Status: Uncommon in high elevation, mossy forest.

Sundamys muelleri (Jentinck, 1879). Notes Leyden Mus. 2:16.
Distribution: Southern Burma to Palawan; Philippine records from Palawan faunal region only.
Status: Common in forest habitats from lowlands to mossy ridgetops.

Tarsomys apoensis Mearns, 1905. Proc. U.S. Nat. Mus. 28:453.
Distribution: Known only from the highlands of southern Mindanao.
Status: Unknown; rare in museum collections.

Tryphomys adustus Miller, 1910. Proc. U. S. Nat. Mus. 38:399.
Distribution: Known only from Benguet, Laguna, and Tarlac Prov., Luzon.
Status: Uncommon but widespread in central Luzon.

Hystricidae - porcupines

Van Weers (1978) considered Thecurus to be a subgenus of Hystrix, and continued to recognize H. pumila as a distinctspecies.

Hystrix pumila Gunther, 1879. Ann. Mag. Nat. Hist., ser. 5, 4:106.
Distribution: Known only from Palawan and Busuanga Islands, Philippines.
Status: Locally common to uncommon in lowland secondary and primary forest.

CARNIVORA

Felidae - cats

Felis bengalensis Kerr, 1792. Anim. Kingdom 1:151.
Distribution: Siberia to Pakistan and Bali; in the Philippines, known only from Busuanga, Cebu, Negros, Palawan, and Panay.
Status: Uncommon but widespread in agricultural habitats and forest; heavily hunted.

Mustelidae - Weasels, otters, and badgers

Long (1978) considered *Suillotaxus* to be a subgenus of *Mydaus*, and retained *M. marchei* as a distinct species.

Aonyx cinerea (Illiger, 1815). Abh. Preuss. Akad. Wiss. 1815:99.
Distribution: India to Taiwan and Java; Philippine records from Palawan Island only.
Status: Widespread, but restricted in the Philippines; probably uncommon along coastal rivers and bays.

Mydaus marchei Huet, 1887. Le Naturaliste, II, 9 annee, 13:149-151.
Distribution: Philippines only; records from Palawan, Busuanga, and Iloc Islands.
Status: Geographically restricted and locally moderately common to uncommon in secondary and primary lowland forest.

Herpestidae - Mongooses

Herpestes urva was erroneously listed by Heaney (1986) from Palawan Island.

Herpestes brachyurus Gray, 1837. Proc. Zool. Soc. London 1836:88.
Distribution: Malay Peninsula to Borneo and Palawan; Philippine records from Palawan and Busuanga Islands only.
Status: Widespread, probably moderately common.

Viverridae - Civets

Arctictis whitei is listed as a synonym of *A. binturong* by Honacki et al. (1982), but its status remains questionable in the absence of critical analysis. *Paradoxurus philippinensis* has long been considered to be a subspecies of *P. hermaphroditus* (e.g., Davis, 1962). The report of *Paguma larvata* from Palawan (listed by Heaney, 1986) may be erroneous, and should be regarded as unlikely until specimens are available.

Arctictis binturong (Raffles, 1821). Trans. Linn. Soc. London 13:253.
Distribution: Northern Burma and Yunnan to Sumatra, Java, and Borneo; in the Philippines, known only from Palawan Island.
Status: Widespread, but Philippine populations restricted and uncommon.

Paradoxurus hermaphroditus (Pallas, 1777). In Schreber, Die Saugethiere, 3:426.

Distribution: Sri Lanka to Hainan and Lesser Sunda Islands; throughout the Philippines.
Status: Common in agricultural and forested areas.

Viverra tangalunga Gray, 1832. Proc. Zool. Soc. London 1832:63.
Distribution: Malay Peninsula to Sulawesi and Amboina; throughout the Philippines.
Status: Common in forest, uncommon elsewhere.

ARTIODACTYLA

Suidae - Pigs

Philippine pigs were revised by Groves (1981), who assigned all populations to Sus barbatus, rather than to S. celebensis.

Sus barbatus Muller, 1838. Tijdschr. Nat. Gesch. Physiol. 5:149.
Distribution: Malay Peninsula to Borneo and the Philippines; throughout the Philippines.
Status: Widespread and locally common, but heavily hunted and declining.

Tragulidae - Mouse-deer

Traqulus napu (F. Cuvier, 1822). In E. Geoffroy and F. Cuvier, Hist. Nat. Mamm. 37:2.
Distribution: Southern Indochina to Java and Borneo; in Philippines, recorded only from Balabac and adjacent small islands.
Status: Species widespread and common; Philippine population restricted; locally common but rapidly declining due to heavy hunting pressure.

Cervidae - deer

Philippine deer of the subgenus Rusa were revised by Grubb and Groves (1983), who recognized two species, C. alfredi and C. mariannus. Cervus calamianensis, a member of the subgenus Axis, is generally considered to be a member of the species C. porcinus (Honacki et al., 1982); Grubb and Groves (1983) suggested that these might have been introduced from China. Grubb and Groves also noted the presence of a poorly-defined member of the Cervus nippon group on Jolo; they also note the possibility of its having been introduced and the poor quality of the available material. Until the status of this population is better defined, we exclude it from the list of extant Philippine mammals.
Cervus alfredi Sclater, 1870. Proc. Zool. Soc. London 1870:381.

Distribution: Negros and Panay Islands, possibly Leyte and Samar; extinct on Cebu, Guimaras, and Masbate.
Status: Geographically restricted and rare; heavily hunted, seriously endangered.

Cervus mariannus Desmarest, 1822. Mammalogie; Paris, p.
Distribution: The Mariana Islands and the Philippines; throughout the Philippines except Cebu, Masbate, Negros, and Panay.
Status: Locally common but heavily hunted and declining; local extinctions are common.

Cervus porcinus (Zimmerman, 1780). Spec. Zool. Geogr., p. 532.
Distribution: India to southern China and Indochina; in the Philippines, recorded from only from Busuanga and Culion.
Status: Species widespread and common, but Philippine populations restricted and uncommon.

Bovidae - Cattle and goats

Groves (1969) assigned the Philippine dwarf water buffalo to the subgenus *Bubalus*, rather that to *Anoa*.

Bubalus mindorensis (Heude, 1888). Mem. Hist. Nat. Emp. Chin. 2:4.
Distribution: High elevations on Mindoro only.
Status: Rare and geographically restricted; severely endangered.

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MORPHOMETRY AND PHYSICO-CHEMICAL PROFILES OF LAKES BALINSASAYAO AND DANAO (PHILIPPINES)

Stephen R. Jones and Omar J. I. Delalamon

Morphometry and profiles of temperature, transparency, dissolved oxygen, pH, alkalinity, orthophosphates, iron, chlorides, and specific conductance were examined for two mountain lakes in Negros Oriental.

Profiles suggested the existence of a principal or seasonal storm thermocline near 15 m and possibly a monomolimnion at great depths. Thus, the lakes may be meromictic. Dissolved oxygen profiles were clinograde, with the boundary between trophogenic and tropholytic waters occurring between 5 m and 10 m. Both lakes were poorly buffered and fell within the soft to medium water range. In general, physicochemical conditions indicated a limited productive potential. Comparisons between lake surface waters, inflows, and suspected outflow are discussed.

Lakes Balinsasayao and Danao are located in mountainous, rain-forested, volcanic basins of Sibulan, Negros Oriental, at an approximate altitude of 880m. The lakes are separated by a narrow ridge which, at its minimum, rises 40m above water level and is approximately 70m wide (Fig.1). The lakes have no surface outlets, but apparently are drained through pervious underlying formations.

Though limnological reconnaissance of Balinsasayao and Danao began in the early 1930's (Woltereck, 1941), our knowledge of the lakes remains fragmentary. Recently, information on morphology, surface waters, zooplankton, and fish harvest has been published (Lowrie et al., 1980; Dolar and Perez, 1983; Cadelina et al., 1984), but annual physico-chemical and biological profiles and cycles have not been examined. Thus, we are presently ill-equipped to develop strategies for maximizing protein yields or managing the basins for such commonly suggested purposes as a sanctuary for threatened and endangered species, an agricultural and municipal water supply, hydro-electric and geothermal energy sources, or a national park. This paper provides additional information to that data base requisite for such management strategies. Additional morphological data and initial observations of vertical physico-chemical profiles are presented in this work.

METHODS

Samples were taken weekly during July 1984 in two Balinsasayao embayments and over the deepest portion of the lake. In Danao, samples were collected over maximum depth on one occasion (Fig. 1). Water temperature was measured with a Fisher electronic digital thermometer immediately upon retrieval by a Kemmerer sampler. Light penetration was estimated with a Secchi disk, and specific conductance was measured in situ at 25 C with a Hach conductivity meter. Chemical analyses were performed in situ with Hach field kits (Hach, 1983), all of which follow "Standard Method" (A.P.H.A., 1975) procedures. Depth determination was by sounding line.

MORPHOMETRY

Morphometry of Balinsasayao and Danao is summarized in Table 1. The data were compiled from Lowrie, et al. (1980), Cadelina, et al. (1984), the Philippine Coast and Geodetic Survey (1954) map of the Balinsasayao area, and field observations by the authors.

With respect to length, width, surface area, volume, and shoreline length, Balinsasayao is approximately twice the size of Danao. Mean width, mean depth, and relative depth are similar for both lakes.

Earlier bathymetry indicated a maximum depth of 90 m for Balinsasayao and 55 m for Danao (Lowrie et al., 1980). During the present study, soundings of 97.5 m and 61.3 m, respectively, were recorded. Lake elevations were nearly equal during the earlier and current soundings (Heideman and Erickson, 1987). Close scrutiny of shoreline reference points, lake configurations during July 1984, and the maps of Lowrie, et al., (1980) and the Philippine Coast and Geodetic Survey (1954) suggests this elevation to be approximately 880 m.

The Balinsasayao shoreline development index (2.0) is 40% greater than that for Danao (1.4). This index approaches unity for circular lakes and increases with deviation from the circular (Wetzel, 1975). Shoreline development is of considerable interest because it reflects the potential for development of highly productive littoral communities. The littoral zone is restricted in both lakes, but more so in Danao.

Volume development is an index of form which approaches 0.33 for a conical depression. Most lake basins approximate an elliptic sinusoid and, thus, have a value greater than 0.33 (Neumann, 1959). Lower values occur for lakes with deep holes like Balinsasayao and Danao. Relative depth is a percentage expression derived from the maximum depth/mean diameter ratio. Most lakes have a value less than 2% (Wetzel, 1975). The high values for Balinsasayao and Danao are indicative of a small surface area with respect to depth, a morphometric feature which restricts productivity. There is little superposition of

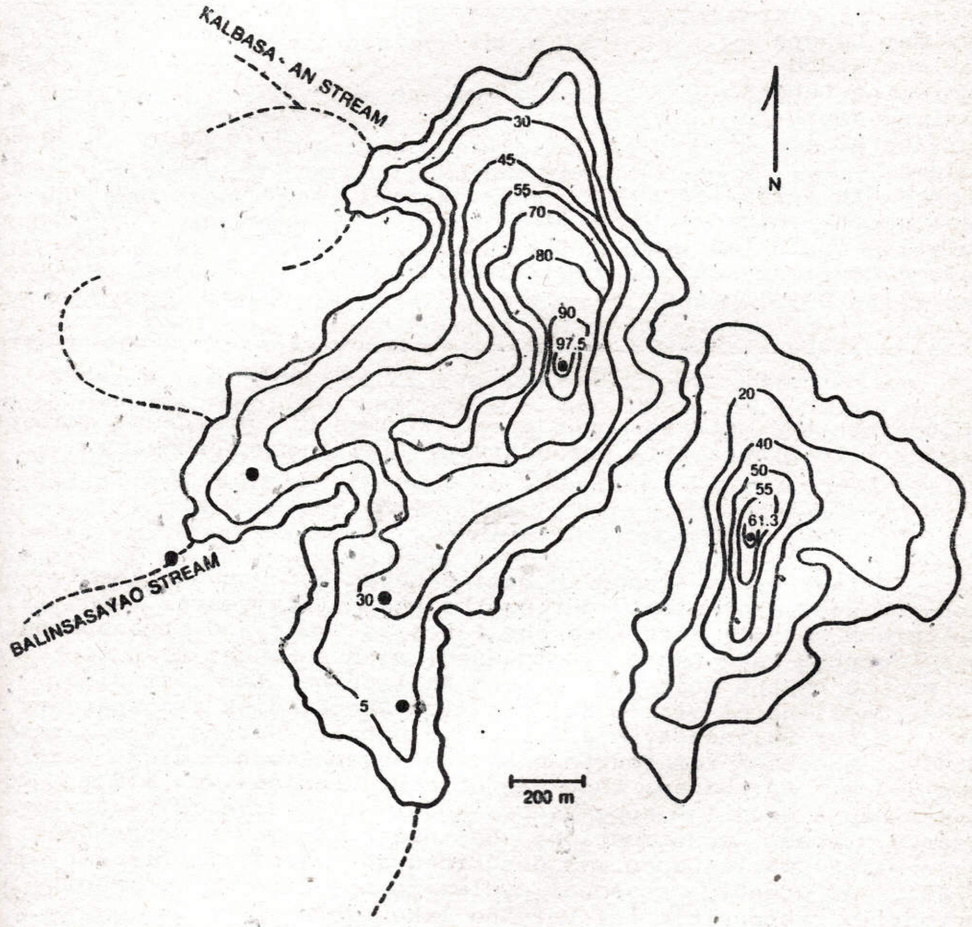

Fig. 1. Map of Lakes Balinsasayao and Danao, showing known contours in meters, sampling stations [ ], and principal tributaries (modified from Cadelina, et al., 1984).

Table 1. Morphometric data for Lakes Balinsasayao and Danao.

	Balinsasayao	Danao
Maximum Length	1.9 km	1.18 km
Maximum Width	1.3 km	0.76 km
Shoreline Length	6	3
Maximum Depth	97.5 m	61.3 m
Surface Area	0.76 km	0.35 km
Volume	9.2 km	4.5 km
Mean Width (area/length)	0.4	0.3
Mean Depth (volume/surface area)	12.1	12.9
Relative Depth (maximum depth/mean dia.)	10%	9%
Volume Development (mean depth/max. depth)	0.12	0.20
Shoreline Development	2.0	1.4

photosynthetic strata over great volumes of profundal waters. Fig. 2 illustrates this productivity-limiting morphometry.

LIGHT

Average transparency in Balinsasayao and Danao probably has not changed appreciably during the past fifty years. In 1933, Woltereck (1941) described the lakes as "soft and transparent," but reported Lake Lanao of Mindanao, with a Secchi disk depth of 6 m, to be the most transparent Philippine Lake studied. In 1982, Cadelina et al, (1984) reported Secchi disk transparency to be 3 m for Balinsasayao and 5 m for Danao. During the present study, the mean for fourteen Balinsasayao Secchi disk readings was 4.3 m. For Danao, the mean of four readings was 5.8 m. Both lakes had a greenish appearance in July 1984. In 1977, following nearby road construction, Balinsasayao was described as "greenish" while Danao was described as "blue" (Lowrie et al., 1980). Apparently, seasonal cycles in the plankton community are primarily responsible for varying lake transparencies.

Although Danao was slightly more transparent than Balinsasayao, their light extinction curves below 5 m were nearly identical. Fig. 3 illustrates the mean attenuation for both lakes. If the lower boundary of the trophogenic zone is the depth receiving only 1% of surface light intensity (Frey, 1969), the trophogenic zone is clearly less than 10 m deep in both Balinsasayao and Danao.

TEMPERATURE AND DISSOLVED OXYGEN

The thermal regimes of Balinsasayac and Danao are poorly understood. Historically, the lakes were regarded as oligomictic (Lowrie et al., 1980), but now there is indication of meromixis at extreme depths.

During July 1984, the maximum vertical temperature range was 3.5 C for both lakes: 26.0 - 22.5 C in Balinsasayao and 25.8 - 22.3 C for Danao. Temperature profiles suggest the formation of feeble, high-lying thermoclines and their frequent smearing by breezes and squalls as in Lake Lanao, Mindanao (Lewis, 1973) (Figs. 3, 4, and 5). The principal thermocline was probably in equilibrium with seasonal storms between 10 and 20 m. The maximum relative thermal resistance (RTR) was 36 and occurred in this stratum. Temperate zone lakes typically have RTR values in excess of 60 during summer thermal stratification (Vallentyne, 1957).

Apparently, typhoons or even an infrequent combination of strong winds, cool air temperature, and possibly heavy rains obliterate the more stable, low-lying thermocline, and a major circulation of the water mass occurs. It is not known if this is oligomixis or merely circulation above a deep monimolimnion (meromixis). According to Silliman University investigators, Balinsasayao last appeared turbid or "slightly reddish" in February 1982 (Professor Ruth Utzurrum, Biology Dept., pers. comm.) This is interpreted as the most recent major circulation in the lake. Earlier circulations have apparently reached even greater depths and resulted in major fish kills. The junior author described a "bloody-red" Balinsasayao in August 1980, with its surface rippling with gasping, dying fishes. Local residents report similar incidents for 1970 and 1973, the latter following a strong typhoon.

A temperature inversion occurred over the bottom of Balinsasayao. If Balinsasayao is meromictic, such as inversion in the monomolimnion would be expected (Wetzel, 1975). Possible heat sources include density currents from warmer overlying strata, metabolic activity, and geothermal. The heat is stabilized over the bottom by high densities sufficient to prevent upward convection.

Horizontally, surface temperature declined slightly with distance from shore. The maximum range noted between 5 m off shore and mid-lake was 1.0 C.

Oxygen profiles for Balinsasayao and Danao were clinograde, with anaerobic conditions existing at 65 m in the former and below 40 m in the latter, (Figure 3). The trophogenic zones (upper 10 m) are strongly supersaturated with surface oxygen concentrations ranging form 8.0 mg/l in Danao to 9.0 mg/l in Balinsasayao. However, percent saturation declines sharply below the trophogenic zone. In Balinsasayac, for example, saturation was 92% at 15 m, but only 39% at 17 m.

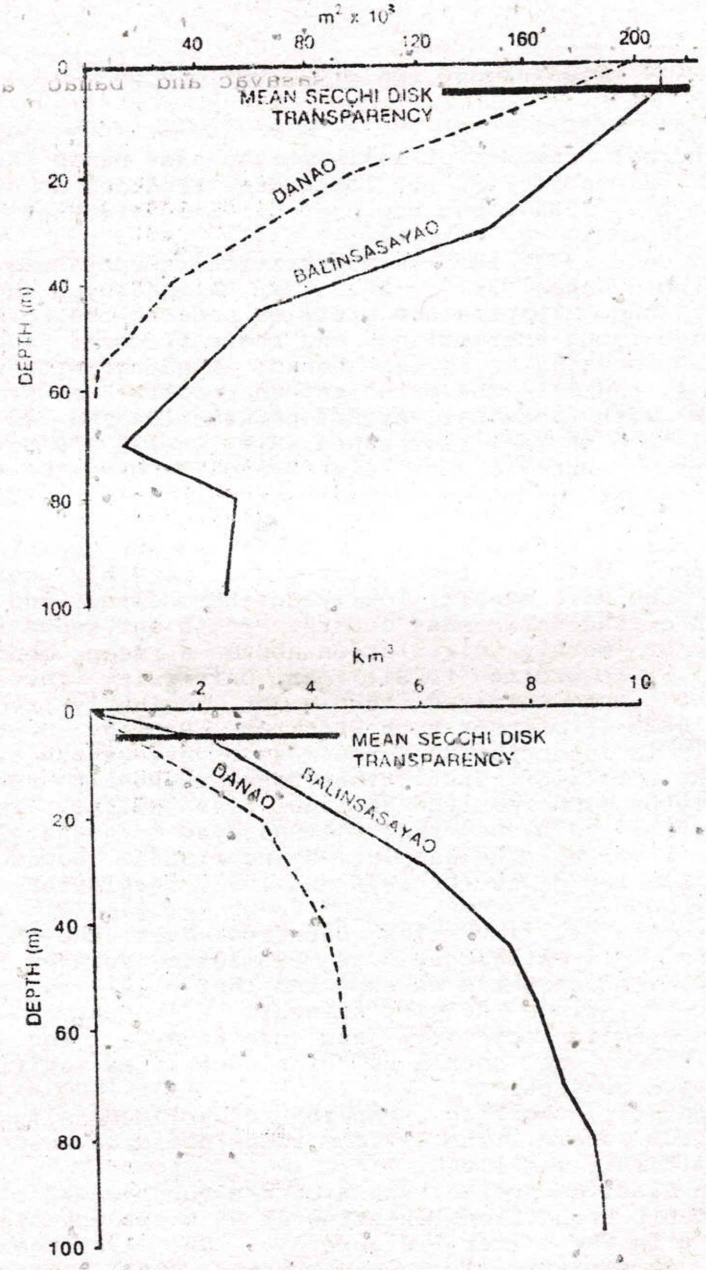

Fig. 2. Hypsographic (upper) and depth-volume (lower) curves for Lakes Balinsasayao and Danao with mean Secchi disk transparency, the lower limit of major photosynthetic activity (based on present study and Cadelina et al., 1984).

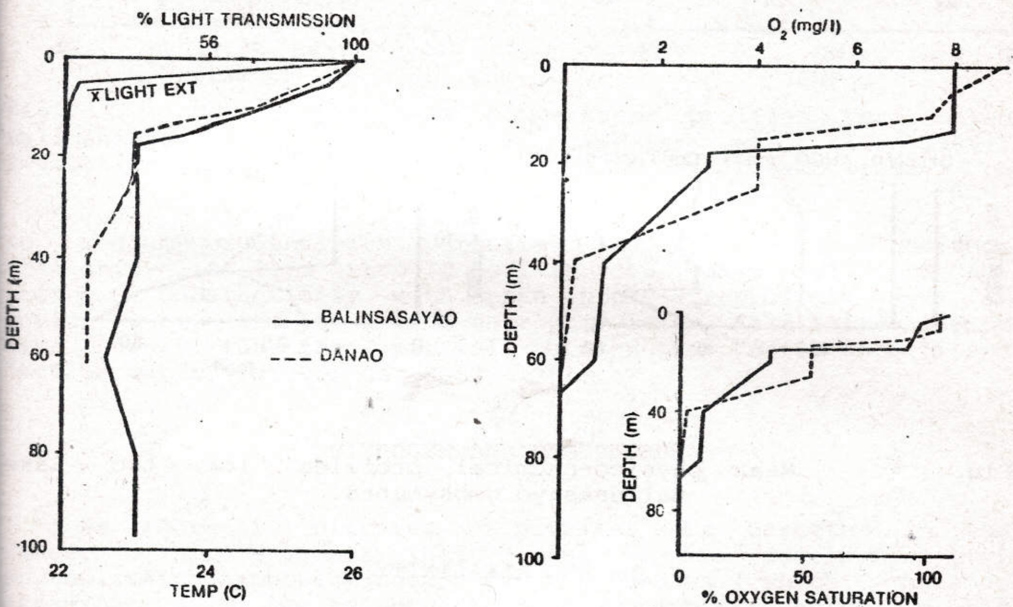

Fig. 3. Mean light extinction curve for Lakes Balinsasayao and Danao and rofiles for mean temperature, dissolved oxygen, and oxygen saturation. (extinction coefficients based on Secchi disk transparency = 5% surface intensity) (Odum, 1971).

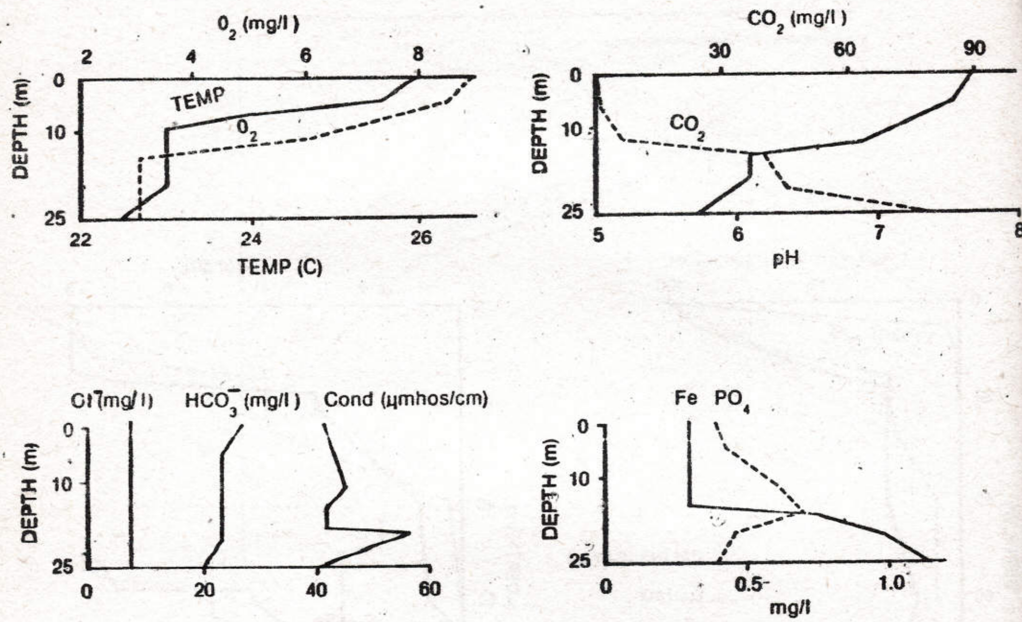

Fig. 4. Mean physico-chemical profiles for two Lake Balinsasayo embayments.

pH AND ALKALINITY

Profiles of pH and bicarbonate alkalinity were negative-heterograde for both lakes (Fig. 6). Balinsasayao was less acidic than Danao, with a mean pH range from 7.8 at the surface to 5.9 at the bottom. In Danao, the surface pH was 7.1, and the bottom pH was 6.2; however, a minimum pH of 5.5 occurred at 25 m. The negative heterograde notches occurred just below the trophogenic zones and were associated with a incresing carbon dioxide level (Fig. 6), presumably from bacterial plates or aggregations of zooplankton, or both (Nagasawa, 1959).

Biologically mediated reactions strongly influence the vertical distribution of pH, carbon dioxide, and bicarbonate alkalinity. These curves, along with the oxygen data, give some indication of the intensity of photosynthesis and decompostion throughout the water column. Although photosynthetic activity, pH, and carbon dioxide levels ascribe an "almost eutrophicd" quality to the epilimnia of Balinsasayao and Danao, the alkalinity profiles suggest a poorly buffered condition and low

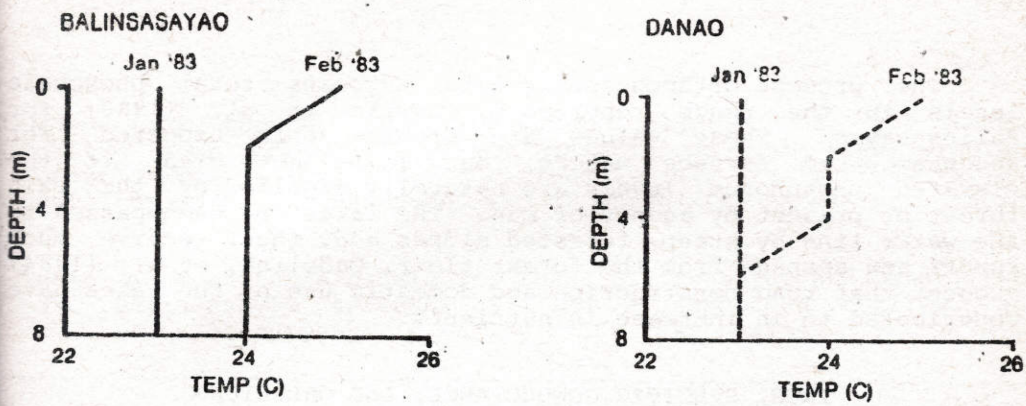

Fig. 5. Upper epilimnial temperature profiles for Lakes Balinsasayao and Danao from Cadelina et. al. (1984), indicating occurence of ephemeral, high lying thermoclines.

to medium productivity potential (Moyle, 1949). Surface alkalinity is less than 30 mg/l in both lakes and does not increase substantially with depth in the tropholytic zone as would be expected for a true eutrophic lake. Alkalinity and pH data sugest that the lakes fall between the "soft water" and "medium water" categories (Reid, 1961).

NITROGEN AND PHOSPHORUS

No inorganic nitrates or nitrites were detected in the lakes. This suggests that during maximum development of phytoplankton populations, the processes which balance assimilation in the trophogenic zone and dentrification in the tropholytic zone may exhaust nitrates completely.

Only tests for soluble inorganic phosphorus (orthophosphates) were conducted during the present study. Such phosphates are a small proportion, perhaps 10% or less, of the total available phosphorus (Pomeroy, 1960). Much or virtually all of the phosphate in a lake may be in protoplasm, bound in organic molecules, or adsorbed to other materials.

Overall, orthophosphate concentration was greater in Balinsasayao (Fig. 7). The range in trophogenic waters of Balinsasayao and Danao was 0.15 mg/l to 0.7 mg/l. Maximum values for both lakes occurred deep in the tropholytic zone.

Elevated hypolimnial phosphate levels are common and are related to an increase in the solubility under hypolimnial conditions. In Balinsasayao, the decline in phosphates just above bottom sediments may be related to phosphorus exchange processes between sediments and overlying water. Much of the phosphorus could, therefore, be in fractions not detectable by the procedures employed (Stumn and Morgan, 1970; Wetzel, 1975).

The present orthophosphate data suggests total phosphate levels in the range reported by Lowrie et al. (1980) for Balinsasayao. These values are greater than expected for uncontaminated surface waters, but it is not clear if the elevated phosphorus levels are naturally supplied by the rain forest or present by agency of man. The lakes are encompassed to the water line by steep, forested slopes and, thus, receive much runoff and seepage from the forest floor. Cadelina, et al. (1984) suggest that road construction and domestic use of the lakes have contributed to an increase in nutrients.

IRON, SPECIFIC CONDUCTANCE, AND CHLORIDES

The iron profiles for both lakes followed the typical lacustrine pattern, ranging from low values in the epilimnion (0.1 mg/l to 0.38 mg/l) to over 6 mg/l deep in the tropholytic zone where anaerobic conditions promote the formation of soluble ferrous iron (Fig. 7).

Specific conductance (conductivity) is a function of the electrolytes present and proportional to the concentration of dissolved solids. Total dissolved solids are approximately 70% of conductivity (Kimmel and Moon, 1982). Both lakes have similar conductance profiles with peaks approximately 20 m over the bottom (Fig. 7). The decline in conductivity with proximity to the water-sediment interface reflects the poor conductive property of suspensions (Ellis et al., 1948).

There is indication from temperture, phosphate, iron, and conductivity data, including Balinsasayao embayment profiles, that meromixix or density currents occur in the lakes (Figs. 3, 4, 6, and 7). High densities in the deepest strata would, thus, prevent complete homogenization even when all thermoclines are obliterated. The monomolimnion would occur below 40 m in Danao and below 30 m in Balinsasayao. The eventual reclassificaiton of Balinsasayao and Danao as meromictic lakes would not be surprising since meromixis is common in deep tropical lakes (Wetzel, 1975).

Little variation occurred in the vertical distribution of chlorides (Fig. 6). In Danao, the concentration was 7.6 mg/l throughout the water column. In Balinsasayao, the range was from 7.6 mg/l in the upper 60 m to 11.4 mg/l in the deepest strata. Based upon inflow data (Table 2), these concentrations reflect the natural occurring levels derived from soils and formations in the basins.

INFLOW AND OUTFLOW

The four mountains which surround lakes Balinsasayao and

Danao rise abruptly from the water's edge. Thus, the lakes receive much seepage and direct run-off from the steep-sloping forest floor. There are, additionally, six small tributaries confluent with Balinsasayao, two of which are permanent; there

Table 2. Mean surface data for Lakes Balinsasayao and Danao, two Lake Balinsasayao tributaries, and a suspected outflow at resurgence in valley below lake basins.

	Balinsasayao Stream	Kalbasa-an Stream	Valley Resurgence	Lake Balinsasayao	Lake Danao
pH	7.2	7.3	7.4	7.8	7.1
Dissolved Oxygen (mg/l)	7.0	-	-	9.0	8.0
Bicarbonate Alkalinity (mg/l)	27.4	27.4	37.6	27.4	27.4
Carbon Dioxide (mg/l)	3.5	2.8	3.1	0	4.5
Orthophosphate (mg/l)	0.5	0.3	trace*	0.4	0.15
Iron (mg/l)	0.3	0.2	0.1	0.38	0.1
Chloride (mg/l)	7.6	15.0	7.6	7.6	7.6
Conductance (umhos/cm)	46	53	-	43	42
Water Temperature (C)	20.0	20.3	23.1	26	25.8

*trace in solution but appreciably more adsorbed on particulates

are no known permanent Danao tributaries (Paul Heideman, University of Michigan, pers. comm.).

The largest Balinsasayao tributary, Balinsasayao Stream, and one of the smallest, Kalbasa-an Stream, were sampled above points of use by man (Fig. 1). Thus, the data should reflect pristine conditions. Stream data and surface data for the lakes are summarized in Table 2.

In general, the stream data is quite similar to surface data for the lakes. Lacustrine photosythesis was responsible for the major differences. Both streams were very clear and flowed under luxuriant vegetation, thus light intensity was low. The flow rate in Balinsasayao Stream at aproximately 150 m above lake confluence was estimated (by the method of Robins and Crawford, 1954) to be 24.1 dm /sec. Average gradient at the sampling point was 242 m/km. In like fashion, the flow rate of Kalbasa-an Stream was estimated to be 0.3 dm /sec at some 70 m above the lake. No rainfall occurred over the lakes during the 48 hours preceding the measurements.

Subsurface drainage from Balinsasayao during the 1983 dry season resulted in an approximate 2 cm/day fall in water level or an estimated outflow rate of 14,600 m /day (Heideman and

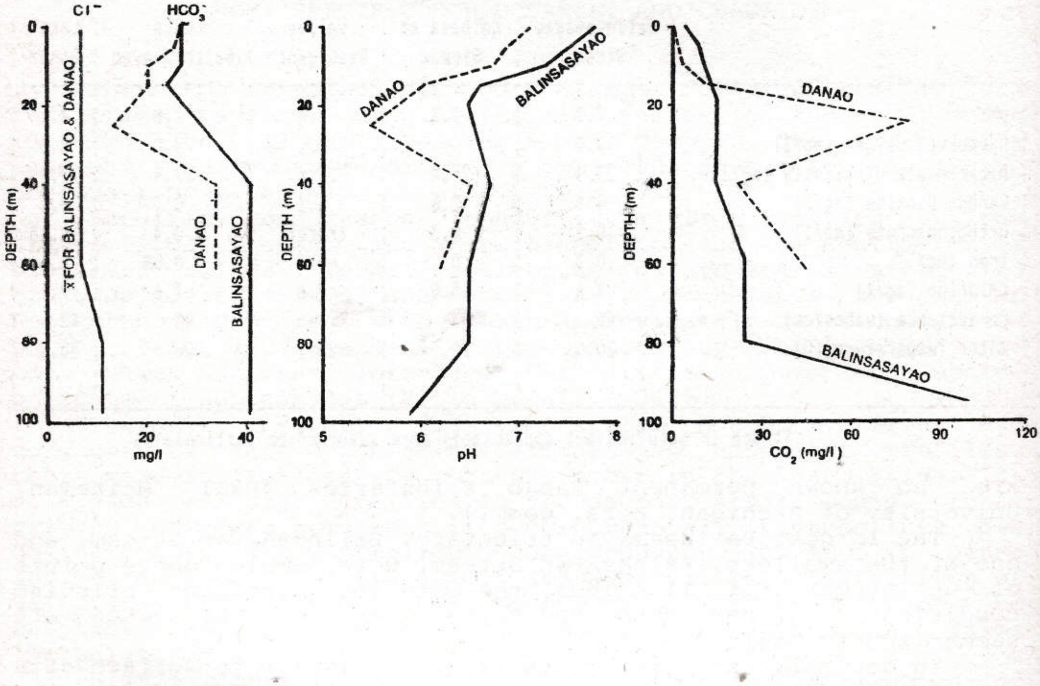

Fig. 6. Profiles for mean bicarbonate alkalinity, chlorides, pH, and free carbon dioxide in Lakes Balinsasayao and Danao.

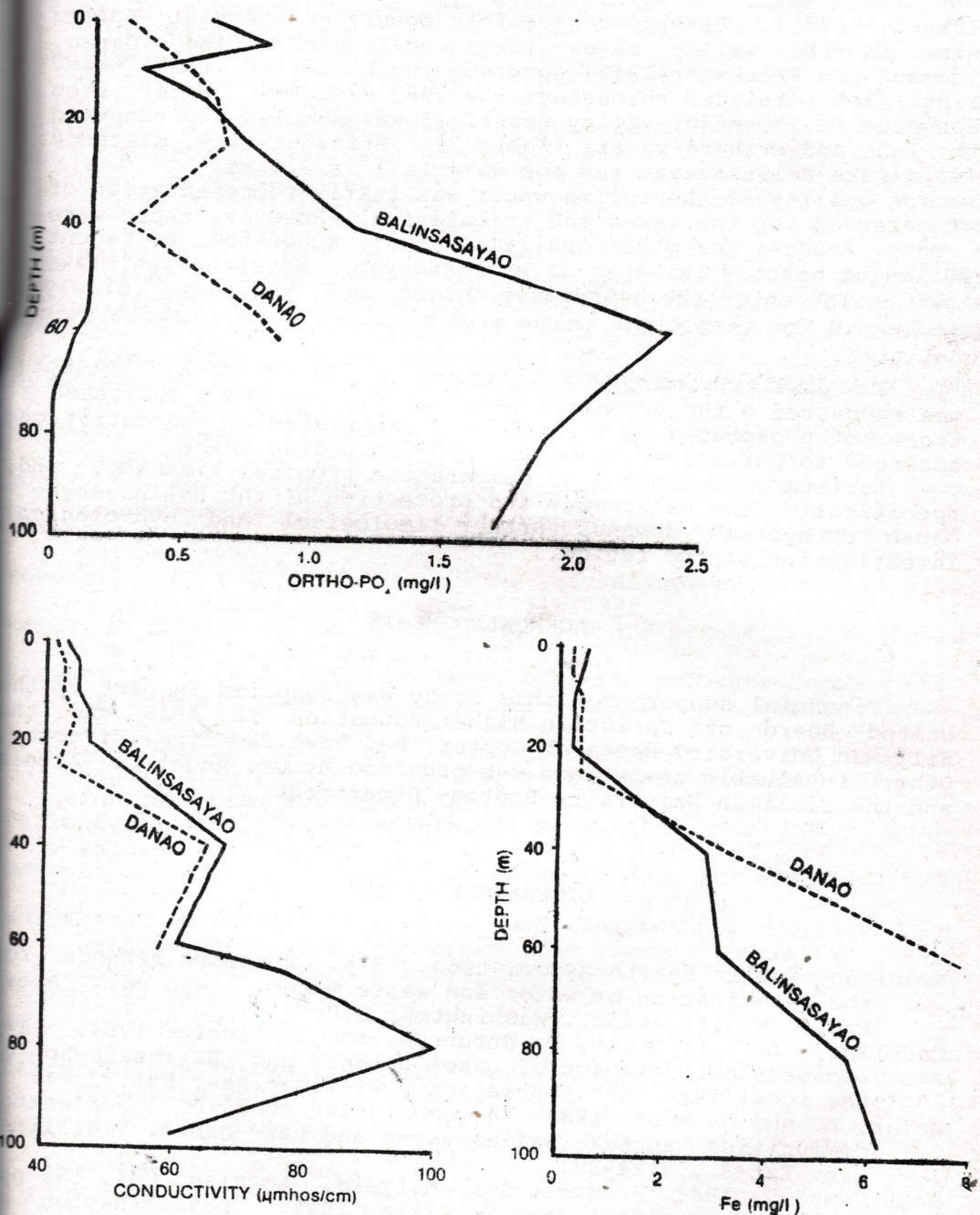

Fig. 7. Profiles for mean orthophosphates, conductivity, and iron in Lakes Balinsasayao and Danao.

Erickson, 1987). Resurgence possibly occurs at the vast spring system in the valley below lakes Balinsasayao and Danao. Heideman and Erickson (1987) suggested such, noting that heavy spring flow persisted throughout the 1983 drought. Water from resurgence at the major valley waterfall was sampled and compared with lake and tributary data (Table 2). Straight-line distance between Lake Balinsasayao and the waterfall is 3.5 km.

The quality of the spring water was fairly representative of that observed for the lakes and tributaries. However, there were no odor, taste, or other qualities that suggested a recent hypolimnial history in Danao or Balinsasayao. Nevertheless, lake water could enter the goundwater system and percolate slowly enroute to the resurgence below with mitigation of tropholytic qualities.

One possible indication of recent lentic or surface history was suggested b the orthophosphate tests. The tests indicated a trace of phosphates in solution and appreciable concentrations adsorbed to particulate matter in the resurging water.

Further development of comparative tropical limnology and, specifically, the management and protection of the Balinsasayao - Danao ecosystems demands further limological and hydrological investigation of the region.

ACKNOWLEDGMENTS

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The Climate and Hydrology of the Lake Balinsasayao Watershed, Negros Oriental, Philippines

Paul D. Heideman and Keith R. Erickson

Climate variables were recorded and a water budget calculated for the Lake Balinsasayao catchment area, 302 ha of submontane forest surrounding a 76 ha lake 14 km west of Dumaguete City on southern Negros Island. Mean annual temperature at the Lake was 22°C, 5.4° cooler than Dumaguete City. Rainfall July 1982—June 1983 was 2372mm, three times that at Dumaguete City. Monthly rainfall at Lake Balinsasayao was highly correlated with that at Dumaguete City, although annual rainfall at the lake is estemated to be about 3100 $\pm$ 300 mm, over 2.5 times that at Dumaguete City. Evaporation accounts for less than 15% of the 16,500 m^3 of water lost daily from the Lake. Since the Lake has no surface outlet, the remaining 85% must be lost through seepage. Available evidence suggests that seepage from Lake Balinsasayao is the source of the springs that join to form the Colo River. Annual evapotranspiration at the Lake was about 1700 mm, both during this study and according to data taken by others, July 1983 - June 1984. Almost 75% of total rainfall on the forest was lost through evapotranspiration during the 1982-83 study period; during the following twelve months, a wetter period, exapotranspirative losses were about 50% of total rainfall. Both annual evapotranspiration and percent runoff figures are higher than those recorded in most other studies on Southeast Asian forest catchments. The results of this study suggest that development of the Lake area as either a hydroelectric power source or a tourist resort would prove unprofitable.

Lake Balinsasayao and the surrounding primary forest (Fig. 1) have been the center of controversies regarding use. The area is currently designated as a wildlife sanctuary and also supplies clean drinking water to communities downslope, but an increasing fraction of the forest is being cleared for subsistence farming. Proposals that the area be extensively developed for tourism, as a water source for irrigation, as a geothermal power source, as a hydro-electric power source or as a protected national park have stimulated a sharp debate. The Lake Balinsasayao area has also become established as an important site for research in terrestrial ecology in Southeast Asia (Rand and Rabor, 1952; Alcala and Brown, 1969; Rabor et al, 1970; Brown and Alcala, 1970; Alcala and Alcala, 1970; Alcala and Carumbana, 1980; Heaney et al., 1981; Antone, 1983; Heaney and Peterson, 1984; Erickson and Heideman, 1984; Utzurrum, 1985; Heideman, 1987; Heideman et al., 1987). The conflicts over use of the area take place in the context of an in-

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Despite the fact that hydrological data are essential to any ecologically and economically sound land - and water - use program, as well as to scientific and applied field research, no such data are available for the Balinsasayao region. The climatological data available for the permanent weather station 14 km away at a lowland coastal site, Dumaguete City, are inadequate because weather patterns often vary greatly over short distances along an elevational gradient, and the climate of Dumaguete City is likely to be dissimilar in important aspects to that of the lake region, some 800 to 1200 meters higher.

There are few studies on the hydrology of forested catchment areas in Southeast Asia (see Low and Goh, 1972, and Whitmore, 1984, for reviews), or in the Philippines (Baconguis, 1980). Such studies are imperative for planning either development or conservation; given the differences between nearby locations, the paucity of hydrological studies is even more serious.

Here we present hydrological information from twelve months of climatological data taken at Lake Balinsasayao, with comments on records provided by Dr. R. Cadeliña and B. Maata (Cadeliña, 1986; Cadeliña and Maata, unpublished data) from twelve additional months. The goals of the paper are (1) to provide a description of the climate of the Lake Balinsasayao region, (2) to calculate a water budget for Lake Balinsasayao and the surrounding catchment area, and (3) to relate the climate of the lake region to the climate of southern Negros island.

Study Area

The study site is on the island of Negros, an oceanic island of 13,670 km^2 located between latitudes 9 and 11 degrees north (Fig. 1). A north-south mountain range runs along the axis of the island, including several peaks of over 1800 m in the north and central part of the range that connect via a series of low ridges with several more peaks of up to 1800 m in the south. The study area, Lake Balinsasayao and its 302 ha watershed, is situated in the southern mountains. Lake Balin sasayao and the adjacent smaller lake, Danao, are located on the eastern slope of this southern knot of mountains at elevations of 830 and 846 m, respectively (Fig. 1). No published geological description is available for the site, but two hypotheses have been proposed for the origin of the lakes. The first suggests that a volcanic cone, Mt. Guintabon (1240 m elev.), dammed two streams arising on the slopes of Mt. Guinsayawan to the west, forming the two lakes (Alcala et al., 1981) and at lower elevations creating a number of small ponds that have entirely or partially filled with silt. The second hypothesis is that the lakes are irregularly shaped crater lakes formed by explosive eruption (Wernstedt, 1953).

The two lakes are separated by a ridge only 100 meters wide at the narrowest point. The surface of Lake Danao is 16 meters higher than the surface of Lake Balinsasayao, suggesting that the dividing ridge is composed of impermeable rock (Alcala et al., 1981). The tops of the steep-sided ridges surrounding the lake range from 900 to 1200 m in elevation. Most of the slopes are between 20 and 70 degrees, with an average of approximately 40 degrees. The soils are volcanic, moderately acidic and of moderate to high fertility (Lowrie, 1983). Neither lake has a surface outlet; water loss from both is entirely due to seepage and evaporation. According to investigators at Silliman University, the lake level has dropped an average of about 200 mm per year over the past 5-10 years, and a local settler at the lake told us that the lake has dropped about three meters over the last 12 years. About two or three kilometers below Lake Balinsasayao a stream forms from a series of springs along a 300-meter length of the valley floor. We believe that the springs are fed by the seepage from the lake (see discussion and Alcala et al., 1981).

As of 1984, about 75 - 85% of the 302 ha area drained by Lake Balinsasayao was covered with primary mixed dipterocarp-oak-laurel forest; the remainder was second growth and recently-cleared forest planted in subsistence crops. We estimate that about 5 - 10% was cleared in the three year period from June 1981 to June 1984.

Climate of Negros Island

The climatic patterns on Negros are determined primarily by the two monsoons of the Asiatic mainland. The southwest monsoon from April or May through October is characterized by southwest winds that are due to low pressure systems that develop over the Asian continental land mass through summer heating of the land surface. The northeast monsoon from November through January produces northeast winds caused by air movement from the polar anticyclone centered near Lake Baikal (Ramage, 1971). During the months of February, March, and early April neither monsoon has much effect, and the climate is dominated by the prevailing northeastern trade winds. The effects of the monsoon and trade winds may, however, be strongly modified locally by the interaction of the monsoon winds with local geographic and orographic features (Lockwood, 1974; Ramage, 1971).

The monsoon winds produce the general annual climatic pattern of Negros, but the monsoon is " . . . only superficially a very orderly phenomenon" (Ramage, 1971), and minor or major changes in the timing of events, along with the occurence of severe cyclonic storms, make the actual climatic pattern of any given year unpredictable. Shifts in the position of high and low pressure systems may cause great changes in weather over large areas, as apparently occured during the first half of 1983, resulting in drought on Negros and weather that was either unusually wet or unusually dry throughout Southeast Asia and the Pacific.

In general, the monsoons bring warm, moisture-laden air to Negros, with concomitant precipitation, while the northeastern trade winds bring cooler air and less rain. In each case the moisture-laden winds rise when they encounter the mountains. As the rising air expands and cools, moisture condenses and precipitates out as rain on the windward slopes of the island. The result is frequent and often heavy rains on the coasts of the island facing the incoming monsoon winds, and lower rainfall on the opposite slopes because the air has been dried by precipitation and descent from the central mountains. Under these conditions, mountain and sea breeze circulation can still be strong enough to lead to vigorous afternoon showers on the leeward side of islands (Ramage, 1971); this greatly moderates the effects of the monsoons in some areas. In contrast, the northeast trade winds bring drier air and much less precipitation to all of Negros (Wernstedt, 1953), and this period with the transition months constitutes the dry season of February through May, only moderately dry on the northeast coast, but extremely dry on the south and west coasts

The interaction of the monsoons with the topography of southern Negros produces two different annual patterns of rainfall, one on the west and south slopes of the island (Fig. 2b), and the other on the east slope (Fig. 2a). The west and south slopes receive most rainfall from the southwest monsoon in the months of June through November, intermediate amounts of precipitation during May and December, and very little during the months of January through April (Fig. 2b). The east slope of the island is far less seasonal, receiving moderate amounts of rain from both the southwest and northwest monsoons, and lower amounts from the northeast trade winds from February through April (Fig. 2a). Thus Dumaguete City, on the east coast, experiences a mild wet season (June-January) during the monsoons, and a mild dry season (monthly rainfall one-half to one-third of wet season months) during the period dominated by the northeast trade winds. The climate of Dumaguete City is classed as "seasonal" using Schmidt and Ferguson's modification of Moh's Q index (Q=no. months $<$ 60 mm/no. months$>$ 100 mm X 100; see Whitmore, 1984), with a Q value of 86 (range for the class is 33 to 100).

METHODS

Data were collected each month during two to three and one-half weeks at the site of the Silliman University cabin (Fig. 1) on the north shore of the larger of the two lakes from 27 June 1982 through 20 June 1983. Rainfall and other weather records for a number of sites on Negros were also obtained from the Dumaguete City Weather Station and from printed sources (Wernstedt, 1953 and 1972; Manalo, 1966).

We took morning readings (generally between 0600 and 0800 hrs) of rainfall, relative humidity, maximum and minimum temperatures for the preceding 24 hours, and lake level. We recorded rainfall in two small raingauges (collection area 57 X 32 mm, capacity 150 mm) and one large raingauge consisting of a galvanized metal collection funnel (collection area a square 250 X 250 mm, capacity about 200 mm) which fed into a covered bucket. The two small raingauges collected from 65-100% of the amount collected over the same period by the large raingauge, varying with wind conditions and rainfall intensity. We regard the large raingauge as more accurate, as its design minimized losses due to splash evaporation. Rainfall totals from the small gauge, when used, were adjusted according to their percentage deviation from the large gauge. The monthly rainfall totals in Table 3 and in Figure 2 are based largely on records from the large raingauge. Rainfall records from the larger raingauge provided a continuous record over the entire period, with the exception of a gap, 9-29 July 1982. The precipitation data end 10 days before the end of June 1983. We extrapolated from July rainfall in Dumaguete City (see correlation analysis below) and used records obtained at the study site by R. V. Cadeliña and B. Maata (personal commiuncation) for the last 10 days of June in order to obtain rainfall estimates for those two months. We estimate that our monthly rainfall figure for July 1982 is accurate to ± 50%, and for all other months to ± 10%. The large raingauge was moved to the ridge above the cabin (Fig. 1) each time we were absent from the site, and was tended, if necessary, by our field assistant. Because we were seldom at the site on the first day of the month, our monthly rainfall totals at Lake Balinsasayao are calculated from the second or third day of each month to the corresponding day of the following month. The Dumaguete City rainfall data, 1982-83 were similarly totalled to allow direct comparison. In order to examine the relationship between rainfall at Dumaguete City and the lake, a correlation analysis was carried out on log-transformations of the monthly rainfall totals (excluding July, the month for which we do not have complete records).

Relative humidity was calculated from temperature readings taken with a sling psychrometer. The curent temperature and the maximum and minimum temperatures for the preceding 24 hour period were recorded from two maximum-minimum thermometers kept in the shade of the cabin in the center of a small clearing. Potential evapotranspiration, the amount of water which could be lost to the atmosphere through evaporation and transpiration given the available net radiation, was estimated using the methods of Thornthwaite (1948; see also Thornthwaite and Hare, 1965) and Holdridge (1959). We calculated actual monthly and annual evapotranspiration at the study site using the measurements of precipitation and relative lake level. We noted lake levels occasionally from June to September 1982, and in October we began recording daily level to the nearest half centimeter on a marked post driven deeply into sand and gravel on the lake bottom. The surface area of the lake was obtained from Abregana (1983), and the area of the drainage basin was calculated using a polar planimeter on a photographic enlargement of a 1:50,000, 20 meter contour-interval topographic map (Philippine Coast and Geographic Survey. Ayaquitan, no. 3648 III, 1956).

RESULTS

Temperature

Mean monthly minimum, mean, and maximum temperatures for the study site and Dumaguete City are presented in Table 1. The mean annual temperature was 22.0°C at Lake Balinsasayao, 5.5°C lower than at Dumaguete City. The mean daily temperature range was 6.7°C (minimum 2°C on 3 November and 8 December and maximum 10.5°C on 18 February). In contrast, the annual range of mean monthly temperatures was only 2.5°C. Table 2 presents the 10 lowest and 10 highest temperatures we recorded and the dates upon which they occurred. The coolest temperatures were in January, February, and March, but were only 2°C below the annual mean low temperature. The highest temperatures were mostly in May-August, and were only three degrees higher than the annual high temperatue. Note that on a single day, Febuary 18, we recorded both one of the 10 coldest and one of the 10 warmest temperatures for the year. The daily extremes of temperature were dependent more upon rain and cloudiness than time of year.

Relative Humidity

We obtained no relative humidity measurement of less than 70%; most were above 85%. Most of our readings were taken in the early morning, when relative humidity tends to be at its highest (Richards, 1952), but several readings taken around noon or early afternoon on clear days were also above 85%, and we suspect that relative humidity is generally quite high throughout the day.

Precipitation

Total rainfall for the one year period at the site was 2372 mm (Table 3). Rainfall during the following, wetter 12 months at Lake Balinsasayao was about 3500 mm (Cadeliña, 1986; Cadeliña and Maata, unpublished data). The 1982-83 figure is certainly below the mean annual rainfall for the site, as a severe drought occurred throughout the Phiilppines during the first six months of 1983, apparently due to the shifting of the normal high and low pressure systems associated with the northeast monsoon. At Dumaguete City, rainfall during the first six months of 1983 (Table 3) was the lowest in more than 25 years. The 762 mm of precipitation recorded at Dumaguete City during the period July 1982-June 1983 was only 2/3 of the mean annual precipitation (Table 4). The lake level fell about three meters during the year (Table 3), also suggesting that rainfall was much lower than usual.

The pattern of variation of monhly rainfall over the year at Lake Balinsasayao was similar to that of Dumaguete City ($R^2 = 0.96$, $p < 0.001$, $N = 11$ months), 14 km away, although the lake area received almost three times the precipitation at Dumaguete City (Fig 2, Tables 3 & 4). We estimate mean annual rainfall for the lake area to be 3100 ± 300 mm, based on the amount of precipitation in 1982-84 and on the relationship between precipitation at the lake area and Dumaguete City. Due to the greater rainfall, the climate of the lake region from 1982 to 1984 would be classed as only "slightly seasonal," using Schmidt and Ferguson's modification of Mohr's Q,, or seasonality, index (Whitmore, 1984), with a Q value of 21 (range for the class is 14 to 33).

Catchment Water Budget

In order to obtain the daily or annual water budget of an area, the daily and annual inflow to the area and annual outflow must be calculated. By far the greatest source of water input to this montane basin is rainfall; water is lost through surface flow, subsurface flow, and evapotranspiration. Because Lake Balinsasayao has no surface outlet, losses from the lake are divided between subsurface flow and evaporation. We will first determine the daily water budget of the lake from precipitation and lake level measurements, then use those figures to determine for the forest the relative importance of flow to the lake and evapotranspiration.

Evaporation

An estimate of evaporative water loss was used to determine the relative importance of evaporation and seepage to the lake water budget. Evaporative water loss is dependent upon a number of factors including wind speed, incident solar radiation, reflectivity of the lake, relative humidity, and the magnitude of the difference between air temperature and mean water temperature. We have no direct measures of evaporation from the lake, but we can obtain an estimate of evaporative water loss from the application of a corrective factor to measurements taken by Quisumbing (1936, 1941) in a concrete fish pond at the Bureau of Science in Manila. Quisumbing found that his pans averaged about 1300 mm of evaporation annually with fairly high variation between months from 5 year monthly means of 43 - 73 mm/month from June to December, to 81 - 145 mm/month from January to May. Because evaporative water loss from pans is greater than evaporation from free bodies of water, pan-to-lake coefficients have been determined at many locations in order to estimate lake evaporation from pan evaporation measurements (water loss from pan X pan-to-lake coefficient = estimate of water loss from lake). In general, simple pan-to-lake coefficients are in the range 0.60 - 0.90; we selected a coefficient of 0.70 because the lower temperatures near the lake should result in reduced evaporation compared to lowland areas (Gale, 1972). This procedure provided estimates of daily evaporative water loss of 0.9 - 3.8 mm/day, with a mean of 2.5 mm/day. Evaporation over the 762,000 m^2 surface area of the lake can account for about 1900 cubic meters (2.5 mm/day X 762,000 m^2) of of water loss daily. The use of other reasonable pan-to-lake coefficients does not greatly alter this figure, nor does it affect the conclusions below.

Daily Water Budget

Actually daily water-loss from the lake is well above 1900 m^3. On rainless days at the end of the drought in 1983 the lake level dropped an average of 21.7 mm/day over 35 consecutive days with no measurable rainfall following a long period with almost no rainfall. During that time, all of the streams that fed the lake were dry and all springs had dried up or slowed to a trickle; we suspect that water input from subsurface springs was also negligible, as the daily rate of water-loss was constant over that period. At that rate of water-loss, about 16,500 m^3 of water was lost every day (21.7 mm/day X 762,000 m^3), and, given the volume of the lake, complete replacement of the lake water would require about three years. If about 1900 m^3 per day is evaporative water-loss, then the remaining 14,000 m^3 (88%) must escape as subsurface seepage.

Since daily water-loss from the lake is roughly constant at 16,500 m^3, determining the rainfall and change in lake level over a period of time allows calculation of the amount of water added to the lake by that amount of rainfall. Furthermore, rainfall can be partitioned into the amount entering the lake and the amount lost from the forest as evapotranspiration, assuming that groundwater stores remain constant. This assumption is probably reasonable unless the period is bounded at the beginning by a dry period and at the end by a wet period (or the reverse).

We used a 23-day period in November over which there was no net change in lake level to obtain an estimate of the amount of rain necessary per day to prevent a net change in lake level. The mean daily rainfall over that period was 10.63 mm per day. We round to obtain 10.6 mm as an estimate of the daily precipitation necessary to prevent a net change in lake level.

The 10.6 mm of rainfall required to prevent a net change in lake level can be partitioned into that entering the lake and that escaping through evapotranspiration. If 10.6 mm of precipitation is sufficient to prevent a drop in water level, and 16,500 m^3 of water is lost from the lake each day, then 10.6 mm of precipitation must provide approximately 16,500 m^3 of water to the lake. Of this 16,500 m^3, 8100 falls directly on the lake (10.6 mm X 762,000 m^2 of lake surface) and 8400 must come from run-off in some form. The area drained by the lake is 3,020,000 m^2, and 10.6 mm of precipitation deposits 32,000 m^3 of water on that area, of which 8400 m^3 drains into the lake within the day. The remaining 23,600 m^3 is lost through evaporation or retained in the soil. Some of the latter portion never reaches the soil as a significant fraction is intercepted by vegetation and evaporates directly back into the atmosphere. Kenworthy (1971) found that in lowland dipterocarp forest at Sungei Gombak in West Malaysia, more than 4.5 mm of rain was required before any moisture reached the floor; there are similar findings for dense temperate forests (Shpak, 1971). If we use 4.5 mm as an approximation for the forest in the Balinsasayao drainage basin, then about 18,700 m^3 reaches the ground, and 10,300 m^3 of the rainwater remains on vegetation and is eventually lost through evaporation and transpiration. Thus, this analysis indicates that on these steeply-sloping forested slopes, approximately 74% of the moisture received from 10.6 mm of precipitation normally escapes through evaporation and transpiration within the forest. During the periods of exceptionally heavy rain associated with typhoons, a much larger fraction of the precipitation reaches the lake; Kenworthy (1971) found that up to 99% of a very heavy rain left the forest as runoff. We lack enough data from such periods for even a rough quantitative analysis.

Annual Water Budget

Over the entire year of the study, the lake region received 2732 mm of rain, or 8,966,000 m^3 (2.372 m X 3,780,000 m^2) of water over the area of the catchment. Over the same period the lake lost 6,035,000 m^3 of water (21..7 mm drop in lake-level/day without input X 762,000 m^2 X 365 days). Our records of lake level indicate that the lake level dropped approximately three meters over that period, indicating that 2,285,000 m^3 (3.0 m X 762,000 m3) was lost from the lake without replacement. Therefore, 5,217,000 m^3 (8,966,000 — [6,035,000 — 2,286,000]) of water was lost through evapotranspiration from the forest, assuming no net change in groundwater stores. Therefore,, total evapotranspiration from the forest over the year was 1,727 mm (5,217,000 m^3/3,020,000 m^2), or 73% of total rainfall. Evapotranspiration in the period July 1983 - June 1984 was similar. The same calculations carried out using data from Cadeliña and Maata (Cadeliña, 1986; Cadeliña and Maata, unpublished data) for that period indicate that evapotranspiration was approximately 1750 ± 150 mm, or 50% of total rainfall.

Monthly estimates of evapotranspiration for the forest around the lake are provided in Table 3. We estimate the potential error in these monthly estimates at at least ± 25%, due to the combined errors from possible changes in groundwater reserves, in the measurement of rainfall, and in the measurement of runoff. Evapotranspiration for the months of February through May was probably underestimated because of error due to unreplaced groundwater outflow from the watershed. The total for the year may also underestimate actual evapotranspiration for the same reason, although groundwater stocks were probably replenished to a great extent by the high rainfall in June.

While actual evapotranspiration is limited by the water supply, potential evaporation is a description of how much water could be lost to the atmosphere if moisture is not limited, given the net radiation received (Thornthwaite and Hare, 1965). Although calculations of potential evapotranspiration are frequently lower than observed evapotranspiration in the tropics (e. g., Kenworthy, 1971), potential evaporation at both the lake and Dumaguete City were determined for comparative purposes. Figure 3a shows observed evapotranspiration, potential evapotranspiration (Thornthwaite and Hare, 1965), and rainfall at the lake for July 1982-June 1983, while figure 3b shows potential evapotranspiration and rainfall at Dumaguete City for the same period. Figure 3c shows mean monthly precipitation and mean monthly potential evapotranspiration at Dumaguete City. Potential evapotranspiration at the lake was considerably lower than observed evapotranspiration for most of the year, a result consistent with the general finding that the Thornthwaite method for estimating potential evapotranspiration tends to be low for many parts of the tropics.

Moisture is likely to be limiting to vegetation in the months of December through July in Dumaguete City, but was limiting to vegetation at Lake Balinsasayao only in March, April, and May in 1983. In the wetter period of July 1983 - June 1984 (Cadeliña, 1986; Cadeliña and Maata, unpublished data) moisture was either not limiting at the lake, or was limiting only for a short period in April.

Seepage from the Lake

The roughly 14,600 m³ of water lost daily through seepage from the lake amounts to a loss of about 10.1 m³ per minute, and it is worth speculating on the fate of this water. It is clear that the dividing ridge between the two lakes is composed of nearly impermeable rock, since the water level of Lake Danao is 16 meters higher than that of Lake Balinsasayao. The ridges and exposed bedrock along the west side of the lake appear similar to the ridge dividing the lakes, and we suspect that they may be composed of impermeable rock. In contrast, the northeastern ridge above the lake has the appearance of a dam of jumbled rock and dirt, and numerous springs flow from the opposite side a few kilometers from the lake. These springs join to form a swiftly flowing stream, the source of the Colo River. The stream is much larger than one would expect from the drainage of such a small area, and it maintained a heavy flow even during the drought in 1983, when flow rates had greatly decreased in all other streams in the area. The available evidence supports the hypothesis that Lake Balinsasayao is the source of the Colo River.

DISCUSSION

Long-term records for Dumaguete City indicate that most years have identifiable wet and dry seasons, but that the beginning and end of the wet and dry seasons vary by some months (Heideman, 1987). The amount of rain in any given month is quite variable from year to year (Fig. 3c), and the average rainy season is only about two and one-half times as wet as the dry season.

The pattern of rainfall at the lake was very similar to that of Dumaguete City, but the lake area received almost three times as much rain (Fig. 3a and 3b). The increase in rainfall at the lake is probably due mainly to the effects of orographic cooling. As a result, the dryer part of the year at the lake is shorter and milder than at Dumaguete City. This difference is exemplified by the Q or seasonality, index (Whitmore, 1984), which classes Dumaguete City as seasonal and the lake area as only slightly seasonal.

Rainfall at the study area appears to correspond to the pattern on the eastern slope of southern Negros (Dumaguete and Pamplona, Fig. 2a), with appreciable rainfall in January and February both during the drought in 1983 (Fig. 3a) and during the more normal period of July 1983 to June 1984 (Cadeliña and Maata, unpublished data). This is consistent with the location of the lake some 14 km inland on the eastern slope of the mountains. Nonetheless, the high correlation between the two locations supports our conclusion that the pattern of wetter and drier periods is the same at both sites.

Wernstedt (1953) reported monthly rainfall data from a variety of sites over the island of Negros. His data show that within the two major rainfall regimes, total rainfall may vary between sites by a factor of at least three, even though very few of his sites are the wetter upland sites. Mean annual rainfall at 51 sites on Negros varied from 1320 to 4220 mm (Manalo, 1956), and, in general increased from east to west across the island (Wernstedt, 1953). Wernstedt (1953) compiled a rainfall map of Negros placing Lake Balinsasayao in an area which receives an average annual rainfall of 2030 mm, much less than our estimate of 3100 mm. His values for upland regions depend on data from very few sites, however. There are no upland or inland data points within 20 km of the lake area.

It would be inappropriate to use the figures obtained from the daily lake water budget to calculate an estimate of the annual precipitation required to prevent a net change in lake level. The figure we would obtain, 3900 mm (10.6 mm/day X 365 days), is not meaningful because this implies an unrealistic distribution of rainfall. A significant fraction of the annual rainfall is received when typhoons bring heavy rains for periods of several days, and a high proportion of this water may become runoff (e. g., up to 99% in a catchment in Malaysia; Kenworthy, 1971). Thus, the actual precipitation required to maintain a constant lake level is probably somewhat lower than 3900 mm/year and would vary with the timing of precipitation. In fact, the lake level rose 2-3 meters from July 1983 to June 1984 when total rainfall was only 3500 mm.

The relationship between potential evapotranspiration and precipitation suggests that moisture stress on plants is common through half of the year at Dumaguete City, but is much less common at Lake Balinsasayao. During periods with high potential evapotranspiration and low precipitation, plants may need to restrict growth and reproduction due to lack of water. Moisture stress might occur at Lake Balinsasayao during short periods in many or most years. This does not necessarily imply that moisture stress will be severe, and in fact it appears that the study area receives adequate moisture for plant growth except during drought periods. This is not the case for

Dumaguete City, where mean monthly precipitation approaches or exceeds potential evapotranspiration for only five to seven months per year (Fig. 3c). It is clear that in most years the drier season at Dumaguete City will include periods of moisture deficiency that may be several months in length.

Our estimate that about 1700 mm of water (about 73% of rainfall in 1982-83, and about 50% rainfall in 1983-84) is lost annually through evapotranspiration is near the upper end of the range recorded for Southeast Asian catchments both in quantity and in percent of rainfall (Low and Goh, 1972). Our 1982 - 83 results were very similar to those of Kenworthy (1971), who reported on the water balance of a partially logged watershed of dipterocarp forest at an elevation of 300 - 500 m in West Malaysia. Kenworthy estimated that annual rainfall was 2500 mm, of which 1750 mm (70%) left the system by transpiration and by direct evaporation from the canopy. Only 100 mm (4%) was lost through surface runoff; 650 mm (26%) was lost through subsurface flow. Similar evapotranspiration estimates were obtained for two Amazonian catchments (1720 mm/year by Jordan and Heuveldop, 1981; 1500 mm/year by Leopoldo et al., 1982). In contrast, Baconguis (1980) found a lower value for annual evapotranspiration, 1035 mm (32% of annual rainfall), for a forested catchment in Luzon. The difference in value for annual evapotranspiration may be due in part to the difference in the pattern of rainfall received. The Luzon site receives 97% of annual rainfall during only seven months of the year, much of which may be intense rain during typhoons. That pattern of rainfall is conducive to higher losses to surface and subsurface runoff (see discussion above). In addition, low soil moisture may restrict evapotranspiration during the dry months. Finally, methodological differences in the calculation of evapotranspiration may account for part of the differences between the two sites. Baconguis calculated potential evapotranspiration using the Penman method (Penman, 1948). Empirical evidence suggests that both the Thornthwaite (1948) and Penman (1948) methods of estimating potential evapotranspiration may underestimate actual evapotranspiration in the tropics (e.g., Kenworthy, 1971; Jordan and Heuveldop, 1982).

The fact that the lake level has been dropping suggests that actual annual rainfall over the past years has probably been slightly lower than the long-term average. It is tempting to attribute the lowering of the lake level to the effects of the almost complete deforestation on the island. Although the catchment itself is still largely forested, virtually all of the surrounding forest has been cleared to near the tops of the ridges bounding the basin to the north, east, and south. In the temperate zone 10% or less of rainfall comes from local evaporation (Lockwood, 1974). Temperate forests have been reported to receive 3—10% more rainfall than nearby deforested areas, but this difference may be due to more efficient collection within forests due to decreased wind velocity (Shpak, 1971). The climatic significance of forest may be greater in the tropics where higher evapotranspiration can contribute more to local rainfall. There is little data available on the influence of deforestation on climates in the tropics, but in the Amazon basin 48% of annual rainfall is derived from evapotranspiration (Salati, et al., 1979). Thus, it is clear that deforestation can have a great impact on rainfall, and could have affected rainfall on southern Negros.

From these results we conclude: (1) that the lakes cannot be used as hydroelectric power source because the large daily losses through subsurface seepage cannot be prevented and (2) that circumstantial evidence suggests that local evapotranspiration may contribute substantially to rainfall on the island, with deforestation part of the cause of the drop in mean annual rainfall at Dumaguete City. We recommend that the lake area and other forested mountain areas be kept in forest as a valuable water source, and in an attempt to reduce the adverse climatic effects of deforestation. Southern Negros is fortunate in having this natural supply of clean water that is reliable even during conditions of severe drought; in a time of increasing local and national concern over water supplies, developments that might threaten the area should be considered with care.

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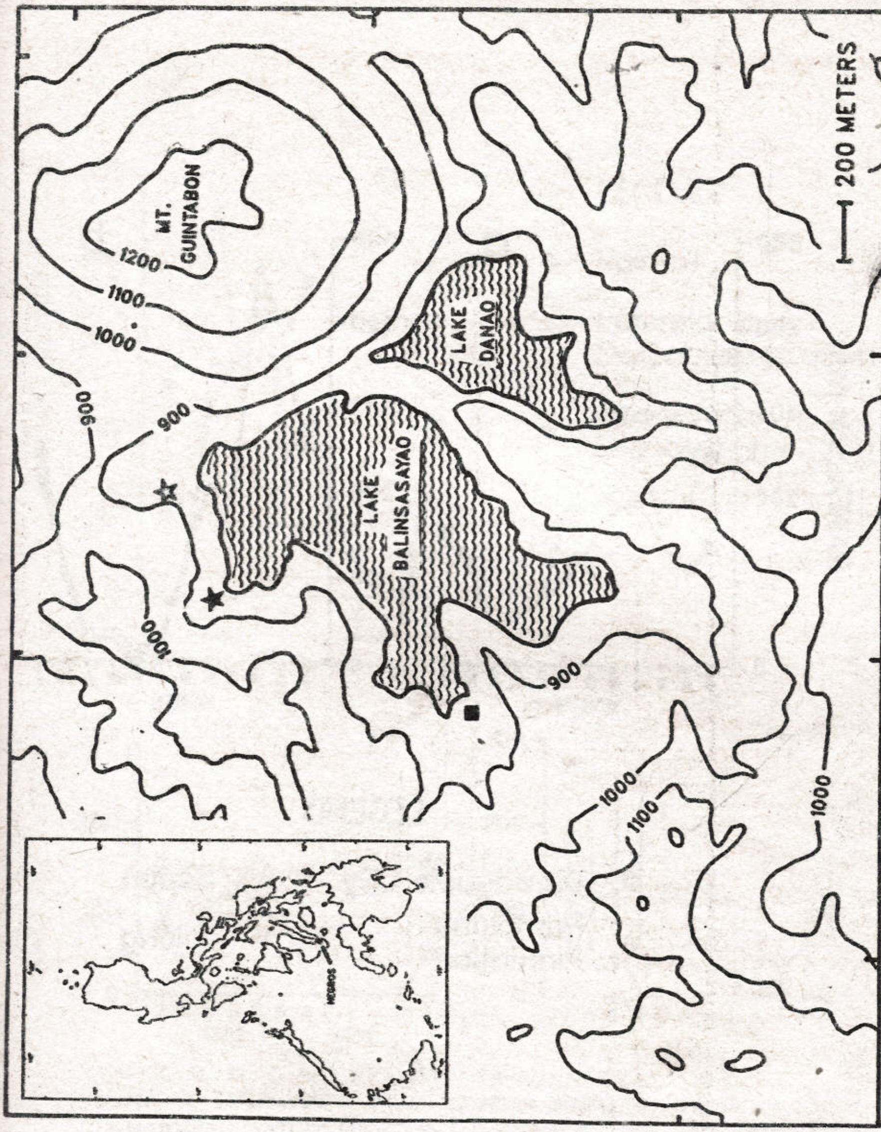

Figure 1. Map of the study sity; inset shows the location of the study site within the Philippines (the top of both figures is north). The solid star marks the primary data collection site; the open star marks the location of the rainfall gauge furing the monthly periods when the authors were absent from the site; the solid square marks the data collection site of Cadelina and Maata (1986.

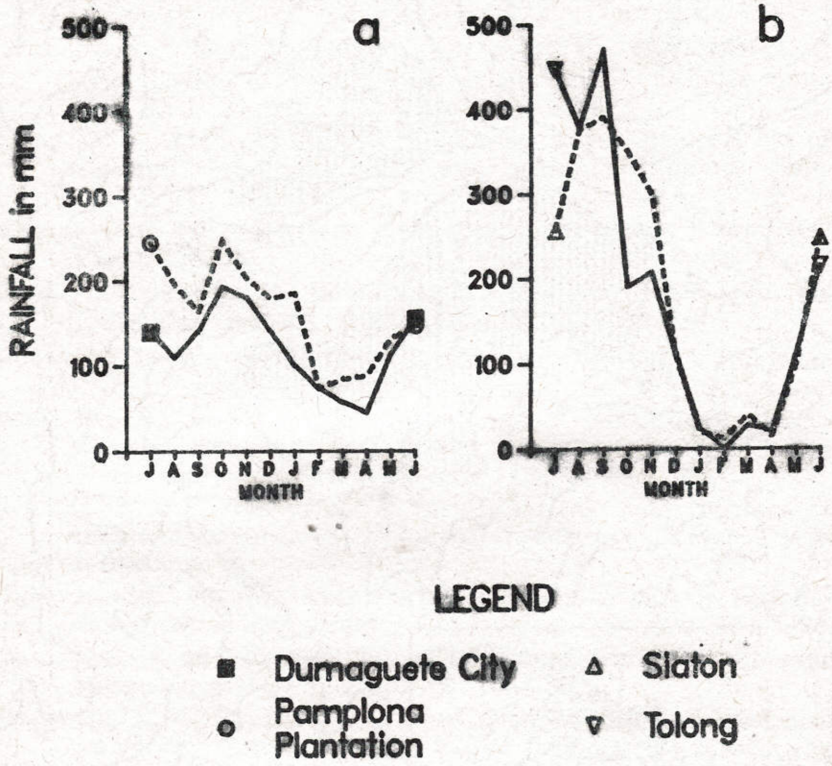

Figure 2. Mean monthly reinfall at four sites on southern Negros. a) Stations on the east slope of the island. b) Staions on the west and south slopes of the island (Data from Wernstedt, 1972, and Dumaguete City Weather Station).

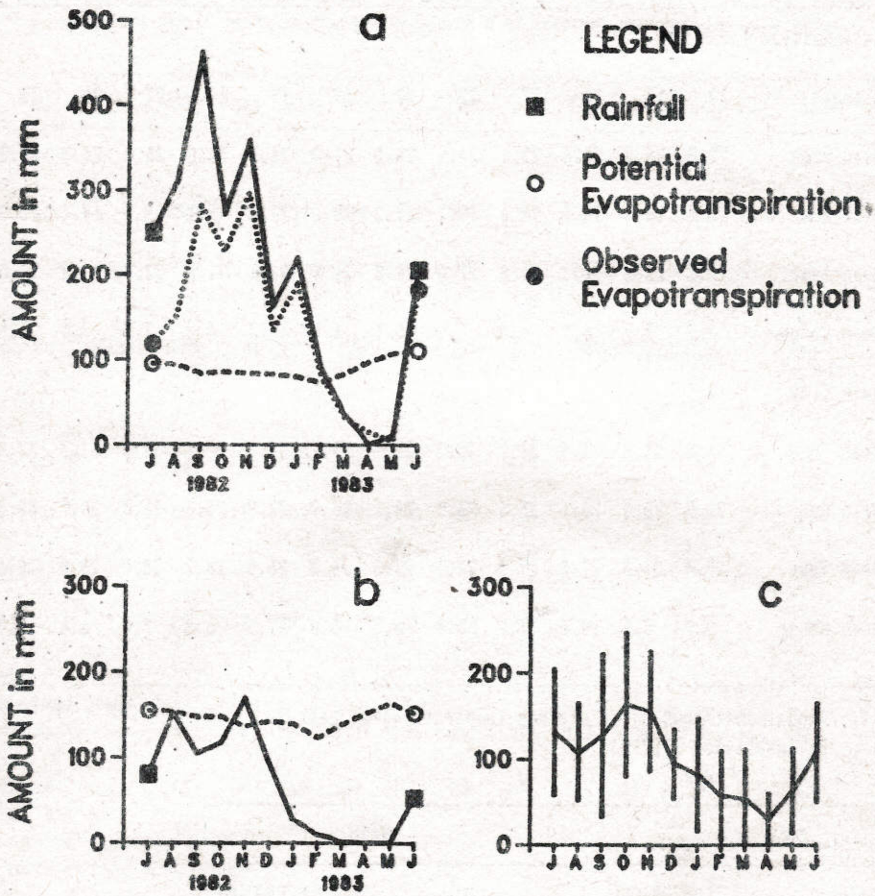

Figure 3. Monthly rainfall, observed evapotranspirtion, and potential evapotranspiration at Dumaguete City and Lake Balinsasayao. a) Monthly rainfall, observed evapotranspiration, and potential evaotranspiration at the Lake Balinsasayao study site from July 1982 through June 1983. b) Monthly rainfall and potential evapotraspiration at Dumaguete City from July 1982 through June 1983. c) Mean monthly rainfall at Dumaguete City for the period 1964 - 1983. The bars represent one standard deviation above and below the mean (Source for Dumaguete City rainfall data: Dumaguete City Weather Station).

Table 1. Monthly mean and annual mean temperatures at Lake Balinsasayao and Dumaguete City (July 1982 - June 1983; June data for Dumaguete City from 1982).

	July	Aug.	Sep.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	Year
Lake Balinsasayao													
N (days)	12	17	10	17	22	22	19	19	17	27	25	13	220
Mean High	25.8	26.2	24.6	25.1	24.9	24.5	24.0	24.7	25.0	26.0	26.7	26.8	25.4
Mean Low	18.6	18.3	18.5	18.6	19.1	19.2	18.0	17.4	18.2	18.5	19.7	20.2	18.7
Mean Temp.	22.2	22.2	21.5	21.8	22.0	21.8	21.0	21.1	21.6	22.3	23.2	23.5	22.0
Mean Range	7.2	7.9	6.1	6.5	5.9	5.3	6.0	7.3	6.8	7.5	7.0	6.6	6.7
Dumaguete City													
Mean High	31.8	31.6	31.9	31.2	30.3	30.4	29.7	30.1	30.1	31.0	31.3	32.0	31.0
Mean Low	22.9	23.0	23.1	23.3	23.9	24.1	23.9	22.8	23.3	26.0	24.7	25.3	23.9
Mean Temp.	27.4	27.3	27.5	27.3	27.1	27.3	26.8	26.5	26.7	28.5	28.0	28.6	27.4
Mean Range	8.9	8.6	8.8	7.9	6.4	6.3	5.8	7.3	6.8	5.0	6.6	7.3	7.1

Table 2. Annual distribution of extreme temperatures at Lake Balinsasayao, 1982-83.

COLD		WARM	
DATE	TEMPERATURE	DATE	TEMPERATURE
6 February	15.5	23 May	28.5
10 "	"	6 June	"
4 "	16.5	14 May	28.0
11 "	"	16 "	"
17 "	"	17 "	"
18 "	"	18 "	"
14 January	"	19 "	"
9 March	"	18 February	"
11 "	"	4 July	"
days in Jan-March	17.0	28 August	"

le 3. Monthly and annual rainfall and evapotranspiration (in mm) on southern Negros, July 1982 - 1983. Approximate change in lake level (July - Sept) or measured change in lake level also provided for same period. Values of observed evapotranspiration most likely to be inaccurate due to probable changes in groundwater reserves enclosed in parentheses.

	July	Aug.	Sep.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	Annual
E BALINSASAYAO													
ainfall	250*	310	457	274	355	164	219	89	35	2	11	206	2372
hange in lake level	100*	200*	500*	-220	-70	-400	-330	-490	-620	-700	-630	-350	-3010
bserved Evapotranspiration	118*	169*	281*	228	297	139	189	(82)	(32)	(15)	4	183	1727*
tential Evapotranspiration Thornthwaite	95	94	84	86	84	83	80	73	84	98	108	111	1080
Holdridge	111	111	104	109	106	109	105	95	108	108	116	114	1296
GUETE CITY													
ainfall	80	152	105	116	168	73	27	20	2	0	1	53	762
tential Evapotranspiration Thornthwaite	155	154	147	147	136	142	139	123	139	152	164	154	1750
Holdridge	137	136	133	136	131	136	134	129	133	135	141	134	1614

imated or extrapolated value

Table 4. Mean monthly and mean annual rainfall (mm) at four sites on southern Negros Island.

	July	Aug.	Sep.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	Annual
1958-1983 Dumaguete City	131	109	128	164	156	95	82	57	53	30	63	108	1776
(N)-Year Means up to 1955:													
(38) Dumaguete City	139	110	141	192	180	140	100	73	57	45	114	154	1445
(11) Pamplona Plantation Co.	245	196	163	247	203	179	185	73	84	88	131	146	1939
(9) Siaton	257	376	390	351	300	111	20	12	40	15	99	248	2307
(5) Tolong, (Poblacion)	447	378	467	191	207	113	23	1	27	20	111	215	1997

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