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The Physical Environment*

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Abstract

A brief review is given of those physical features of San Miguel Bay, Philippines, which have an impact on the Bay's fisheries. These features are: the climatic conditions, notably the strong winds during the northeast monsoon; the oceanographic conditions, notably the estuarine habitats created within the Bay by the freshwater inflow from the Bicol River and by the heavy rainfall; and the siltation of the Bay by upland erosion which is gradually making the Bay shallower, thus reducing those areas legally and physically accessible to commercial-sized vessels (above 3t).

Introduction

San Miguel Bay and the adjacent waters represent the only trawlable area along the Pacific coast of the Philippines, and the area is one of the most important fishing grounds in the country (Simpson 1978).

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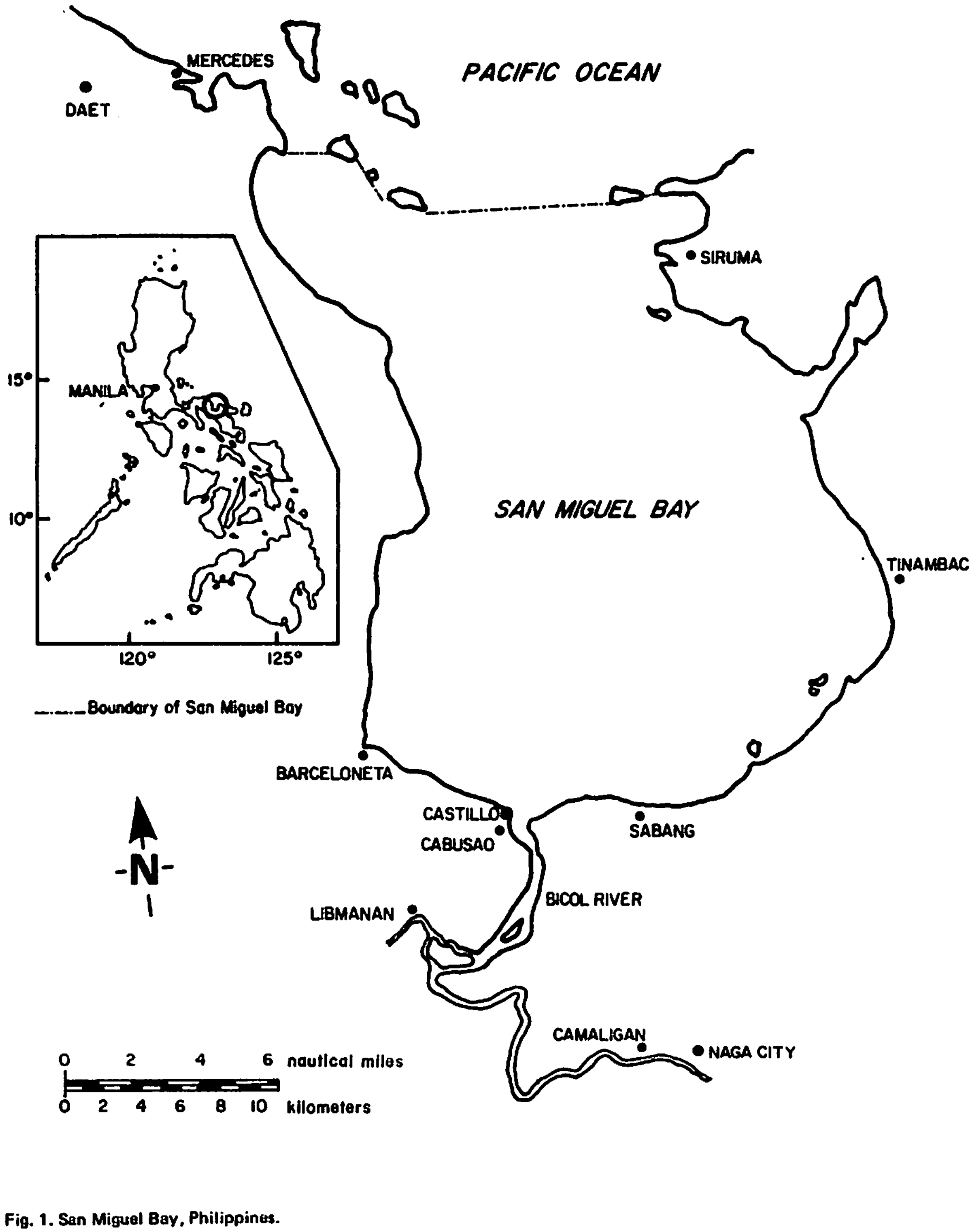

Fig. 1. San Miguel Bay, Philippines.

As elsewhere along the Pacific coast, the fisheries of San Miguel Bay are of a seasonal nature, due to the rough weather prevailing during the northeast monsoon. However, this feature is less pronounced than in other parts of the Pacific coast of the Philippines.

The Bay proper (Fig. 1) is shallow; its average depth at the beginning of the century was 8.9 m (see Table 1 for depth zonation). Due to heavy siltation, mainly from the Bicol River, the average depth has been reduced to 7.4 m, affecting the types of fishing gears that can be physically and/or legally deployed within the Bay. Undoubtedly, the siltation also has a positive effect on the biological productivity of the Bay.

In the following, the major physical features of the San Miguel Bay are briefly reviewed, including climatic factors (winds, rains); hydrography of and freshwater inflow into the Bay; and siltation. The effects of these three features on the small-scale and trawl fisheries are discussed here as background to the detailed presentation of various aspects of the Bay's fisheries included in this report.

Climatic Factors

The major climatic feature along the Pacific coast of the Philippines is the occurrence, in conjunction with the northeast monsoon (October to March), of extremely strong winds which prevent or greatly hinder fishing, especially throughout November and December. Figs. 2 and 3 document the seasonality of the winds and of the rainfall in the area, respectively.

Large trawlers, which generally operate outside the Bay (as defined in Fig. 1) catch fish within San Miguel Bay only during the northeast monsoon in the sheltered northeastern part of the Bay. Small-scale fishermen, on the other hand, sometimes have to stop fishing when the northeast monsoon is at its peak.

The peak of the southwest monsoon (May to July) has no impact on the San Miguel Bay fisheries, and there is no drop in catches during this period (see other contributions in this report).

The annual mean air temperature over the Bay is 27.5°C (Anon. 1975).

Table 1. Past (1907) and present (1980) depth zonation in San Miguel Bay.[a]

Fathom	Past depth zonation[b] (m)	Midrange(m)	Area (km^2)	% of total	Cumulative % of total	Present depth midrange(s)
0 – 3.9	0 – 7.2	3.66	313	37.2	37.2	2.17
4 – 4.9	7.3 – 9.0	8.23	185	22.0	59.2	6.74
5 – 5.9	9.1 – 10.9	10.1	91.3	10.9	70.1	8.61
6 – 6.9	11 – 12.7	11.9	90.0	10.7	80.8	10.4
7 – 7.9	12.8 – 14.5	13.7	41.0	4.9	85.7	12.2
8 – 8.9	14.6 – 16.4	15.6	37.6	4.5	90.2	14.1
9 – 9.9	16.5 – 18.2	17.4	30.1	3.6	93.8	15.9
10 – 10.9	18.3 – 20.0	19.2	19.8	2.4	96.2	17.7
11 – 11.9	20.1 – 21.8	21.0	14.6	1.7	97.9	19.5
12 – 12.9	21.9 – 23.7	22.9	9.0	1.1	99.0	21.4
13 – 13.9	23.8 – 25.5	24.7	4.2	0.5	99.5	23.2
14 – 14.9	25.6 – 27.3	26.5	2.2	0.25	99.75	25.0
15 – 15.9	27.4 – 29.2	28.4	1.7	0.2	99.95	26.9
16 – 16.9	29.3 – 31.0	30.2	0.5	0.05	100.00	28.7
Total	–	–	840	100	100	–
Weighted mean	–	8.9	–	–	–	7.4

[a]Past zonation based on map San Miguel and Lamit Bays, Philippine Coast and Geodetic Survey (PC & GS 4223); present zonation based on bathymetric survey conducted in 1980, and obtained by adding 1.49 m to the midranges of the early depth ranges (see text).

[b]Most of the soundings were made in 1907.

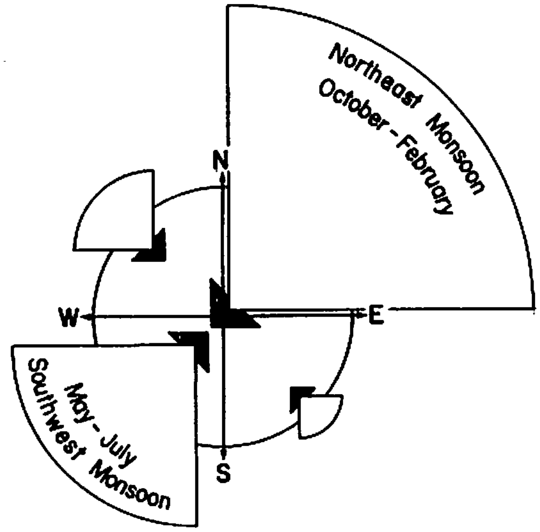

Fig. 2. Schematic representation of wind directions and intensities over San Miguel Bay. Based on daily records (for 1980) obtained from Pili Weather Station, Camarines Sur, near San Miguel Bay.

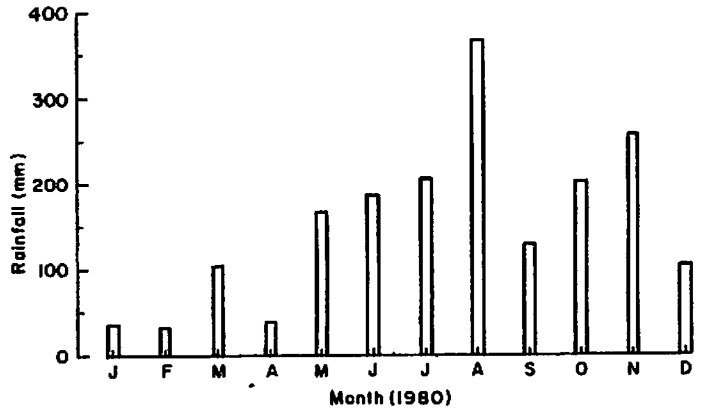

Fig. 3. Rainfall data for 1980, Pili Weather Station, near San Miguel Bay.

Hydrography

Although a number of biological surveys have been conducted in the last decades in the Bay (Pauly, this report), it is only recently that quantitative oceanographic data have been reported from San Miguel Bay. Fig. 4, adapted from Legasto et al. (1975), summarizes the available information on temperature, salinity and oxygen distribution in the Bay; as obtained during a 30-station survey conducted 9-10 November 1974.

Fig. 4C shows the marked impact of the Bicol River water on the water masses within the Bay, a subject to which reference will be made further below.

Fig. 5, which is based on Fig. 4C and 4D is a schematic representation of the vertical distribution of salinity in the inner part of San Miguel Bay. The isohalines in Fig. 5 suggest the existence of a brackishwater wedge high up into the mouth of the Bicol River.

The tides in San Miguel Bay, as along the rest of the Pacific coast of the Philippines are of the semi-diurnal type, with a mean amplitude of 94 cm (Anon. 1979). Fig. 6 shows the tidal oscillations in San Miguel Bay for the 27th of November 1980, as computed from data in Anon. (1979).

Annual water inflow from rivers into the Bay, as computed from data in Anon. (1972) amounts to 2.87×10^9 m^3, 96% of which stems from the Bicol River (Table 2). Mean annual rainfall onto the 840-km^2 Bay is about 3.40 m (Anon. 1975), corresponding to 2.86×10^9 m^3 of rain water. Thus, about 5.73×10^9 m^3 of water is added annually to the Bay, or about 87% of the 6.61 ×

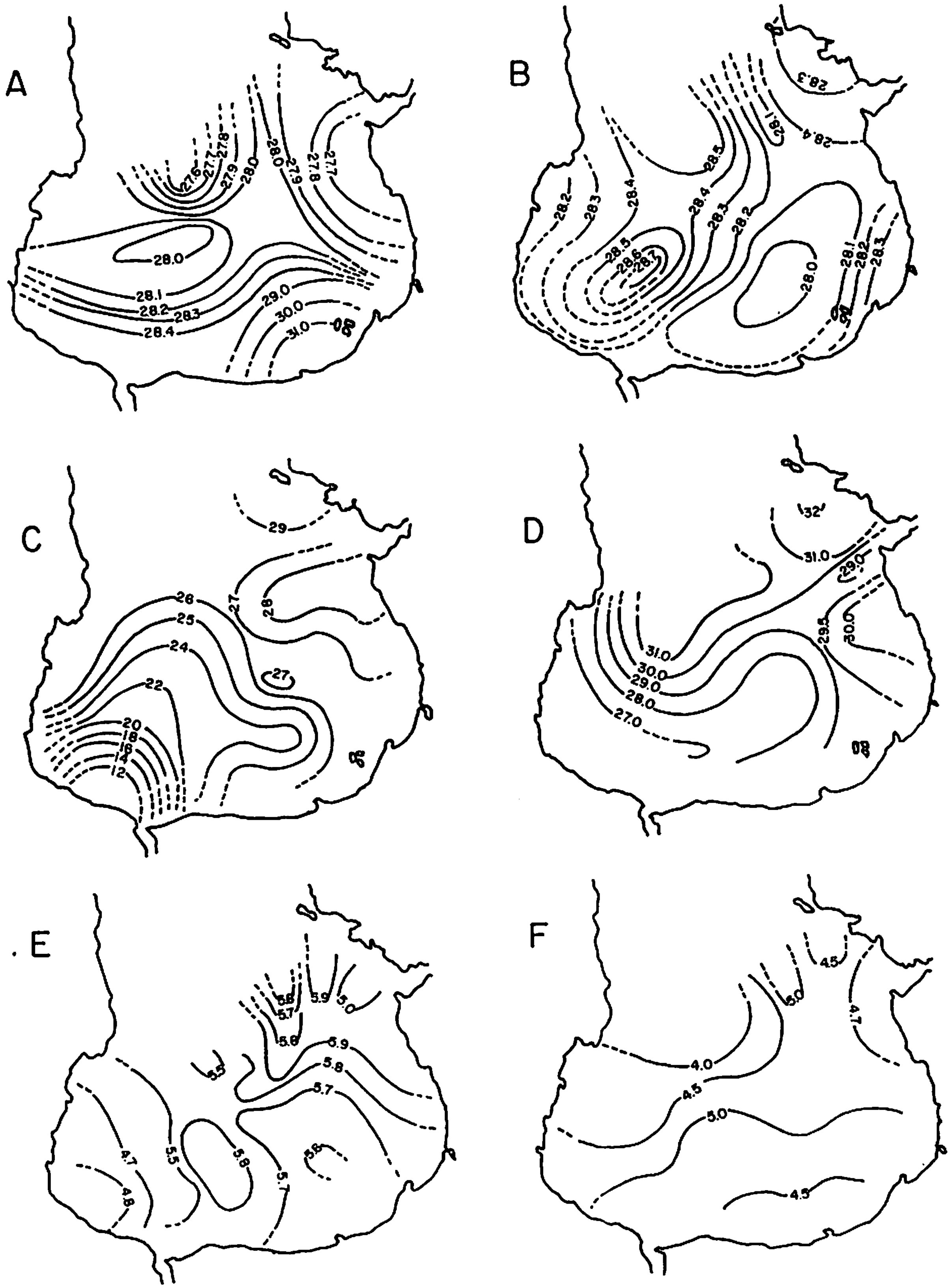

Fig. 4. Hydrography of San Miguel Bay, 9-10 November 1974. Adapted from Figs. 2 to 7 in Legasto et al. (1975) (with permission of F. Gonzales, Director, Bureau of Fisheries and Aquatic Resources, Manila). A: surface temperature (°C); B: bottom temperature; C: surface salinity (‰); D: Bottom salinity; E: oxygen content (ml/l), surface; F: oxygen content, bottom.

10^9 m^3 present at any time in the Bay (on the average) as computed from the present depth of 7.4 m + 1/2 tidal amplitude.

A first estimate of annual evaporation over the Bay can be computed from the empirical equation

$$E = (0.26 + 0.77v) \cdot (e_w - e_a) \quad \ldots \quad (1)$$

where E is the evaporation rate, in mm per cm^2 per day; v is the wind speed in m/sec; e_w is the vapor pressure of water at the temperature of the water surface in millibars; and e_a is the partial pressure of vapor in the atmosphere (Perkins 1974). The following values were used in conjunction with equation (1):

mean annual v = 0.0482, as calculated from a total annual wind run over the Bay of 820 knots, based on data obtained from Pili Weather Station (see also Fig. 2);

e_w = 36.08, as interpolated for a temperature of 27.5°C from Table 29 in Sverdrup et al. (1942);

e_a = 29.22 – 36.08 x 0.81, where 0.81 corresponds to 81%, the mean annual relative humidity over San Miguel Bay (Anon. 1975).

From equation (1), it is estimated that E = 2.04 mm/day, corresponding to 6.25 x 10^8 t of water evaporating annually from the Bay, or about 9.5% of its mean water content.

Flushing time (t_f) for the San Miguel Bay as a whole may be estimated from

$$t_f = (V + P) / P \quad \ldots \quad (2)$$

where V is the total water volume at low water and P is the volume of water entering at each flood, or "intertidal volume" (Bowden 1967).

The figures given above correspond to P = 7.4 x 840 x 10^9 m^3 and V = 0.94 x 840 x 10^9, which leads to an estimate of t_f = 8.87 tidal periods (of 12.4 hr each) or 4.6 days.

As explained in Bowden (1967), estimates of flushing time based on expression (2) are generally underestimates of true flushing time, because the method incorporates the assumption of complete mixing at each tide. Nevertheless, such estimates may be useful, e.g., to assess the *minimum* time that pollutants or nutrients are likely to remain, on the average, in a given estuary.

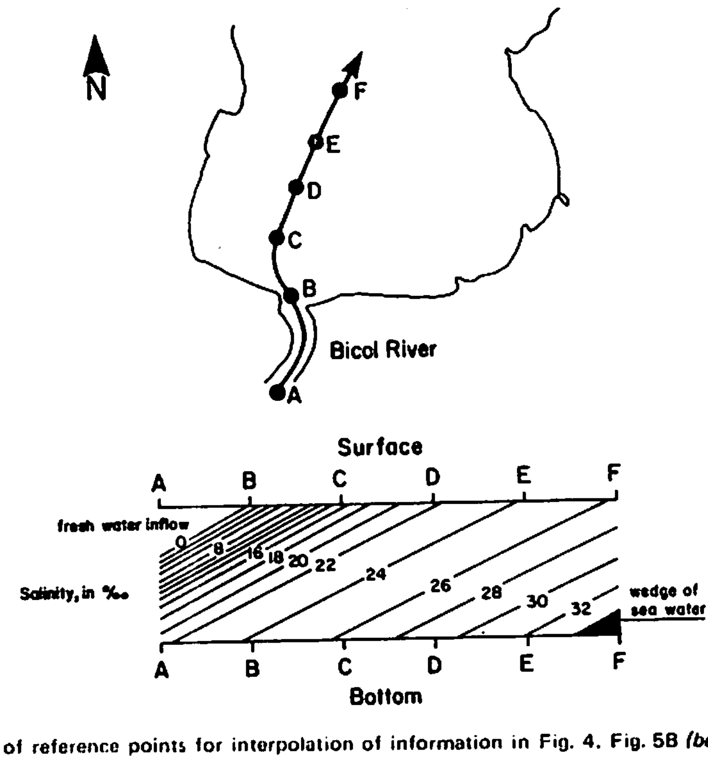

Fig. 5A *(above)*. Positions of reference points for interpolation of information in Fig. 4. Fig. 5B *(below)*. Schematic representation of salinity distribution, November 1974, as inferred from Figs. 4C and 4D.

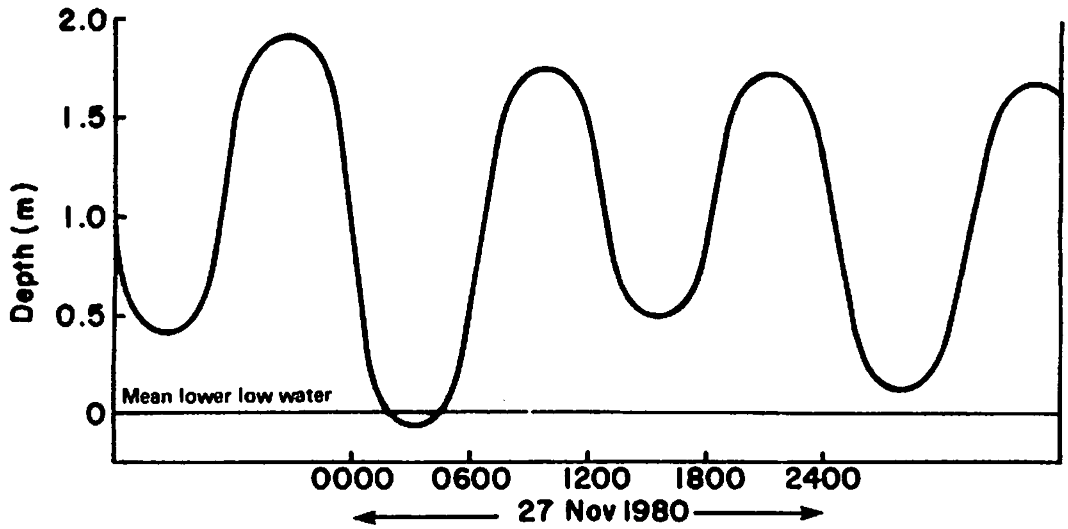

Fig. 6. Tidal cycle in San Miguel Bay, 27 November 1980, based on Philippine Tide Tables for 1980 and used to standardize soundings of bathymetric survey.

Table 2. Annual river water discharge in San Miguel Bay.[a]

RIVERS Months	Bicol River[b] (1966-67) x 1,000 m^3	%	Hinagianan River (1966) x 1,000 m^3	%	Tigman River (1966) x 1,000 m^3	%	Total x 1,000 m^3	%
January	374,054	13.6	6,206	12.1	7,962	10.2	388,222	13.6
February	197,174	7.2	4,513	8.8	6,177	8.0	207,864	7.2
March	170,579	6.2	1,984	3.9	6,201	8.0	178,764	6.2
April	134,883	4.9	1,394	2.7	5,163	6.7	141,440	4.9
May	118,287	4.3	1,991	3.9	5,406	7.0	125,684	4.4
June	104,543	3.8	1,096	2.1	5,610	7.2	111,249	3.9
July	132,314	4.8	3,852	7.5	6,667	8.6	142,833	5.0
August	353,123	12.9	6,682	13.0	6,223	8.0	366,028	12.7
September	299,571	10.9	2,815	5.5	5,323	6.9	307,709	10.7
October	332,441	12.1	3,764	7.3	6,047	7.8	342,252	11.9
November	389,529	14.3	5,731	11.2	7,354	9.5	402,614	14.0
December	137,262	5.0	11,250	22.0	9,475	12.1	157,987	5.5
Total	2,743,760	100.0	51,278	100.0	77,608	100.0	2,872,646	100.0

[a]Adapted from Anon. (1972).
[b]Not including (insignificant) contribution of Libmanan River.

Siltation

Fishermen around the Bay are well aware that it has become much shallower than it was previously. This is also reflected in the fact that landing places, such as Sabang, which were earlier accessible to trawlers have now become so shallow that the trawlers must be unloaded with the help of smaller boats that are dragged through the mud.

No quantitative data were available on the siltation process. For this reason, we conducted, on 27 November 1980, a bathymetric survey in the southeastern part of the Bay (covering 40% of its surface area; see Fig. 7B) using a Furono MG-200* battery-driven echosounder mounted on a fisherman's boat. The depth readings were standardized to mean lower low water by way of the graph in Fig. 6 and isobaths drawn (Fig. 7B) from which a mean depth difference of 1.49 m was estimated with regard to the map of San Miguel Bay showing the greatest bathymetric details (San

*Mention of trade names does not imply endorsement of commercial products.

Miguel and Lamit Bays, Philippine Coast and Geodetic Survey, PC & GS 4223), which has a scale of 1:100,000.

We were informed by personnel for the Philippine Coast and Geodetic survey that the major part of the soundings for this map was made in 1907, or 73 years before our bathymetric survey. Assuming linearity, a rate of silt deposition of 2 cm/yr can thus be estimated, corresponding to a deposition of 1.68×10^7 m^3 of silt per year for the Bay as a whole.

Given the estimated inflow from rivers of 2.87×10^9 m^2 per year, a silt content of the river water of 0.6% (in volume) can be estimated for the Bicol River (which contributes 96% of all inflowing water, see Table 2). This estimate of the silt load of the Bicol River, although seemingly high, is certainly an underestimate. In July 1981, we centrifuged several samples of Bicol River water and separated solids which ranged between 1 and 2% (in volume) of the water samples. The value of 0.6% silt load is based on the assumption of a constant rate of silt deposition from 1907 to 1980.

Deforestation, which is a cause for erosion and siltation, greatly accelerated in the last decade, for which reason one should expect a silt load higher than average in recent years, possibly as much as, for example, the 2.5% reported in Banerji and Singh (1979) from the Sone River in Bihar State, India.

The Bicol River, in addition to coursing through deforested areas also goes through several cities, the major one of which is Naga City (ca. 100,000 inhabitants), the commercial center of Camarines Sur Province. This should add considerably to the material transported by the river waters, notably in terms of domestic sewage.

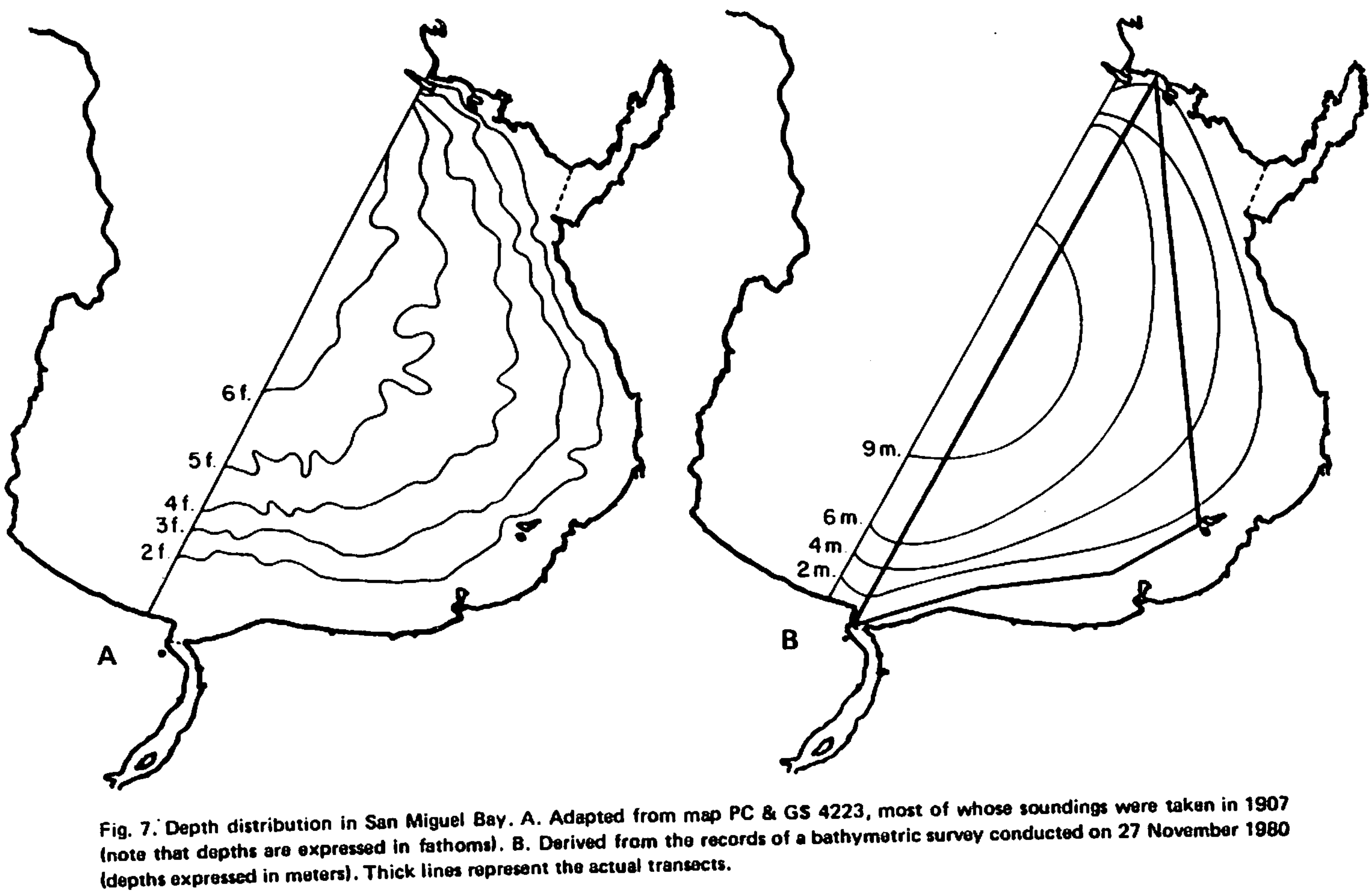

Fig. 7. Depth distribution in San Miguel Bay. A. Adapted from map PC & GS 4223, most of whose soundings were taken in 1907 (note that depths are expressed in fathoms). B. Derived from the records of a bathymetric survey conducted on 27 November 1980 (depths expressed in meters). Thick lines represent the actual transects.

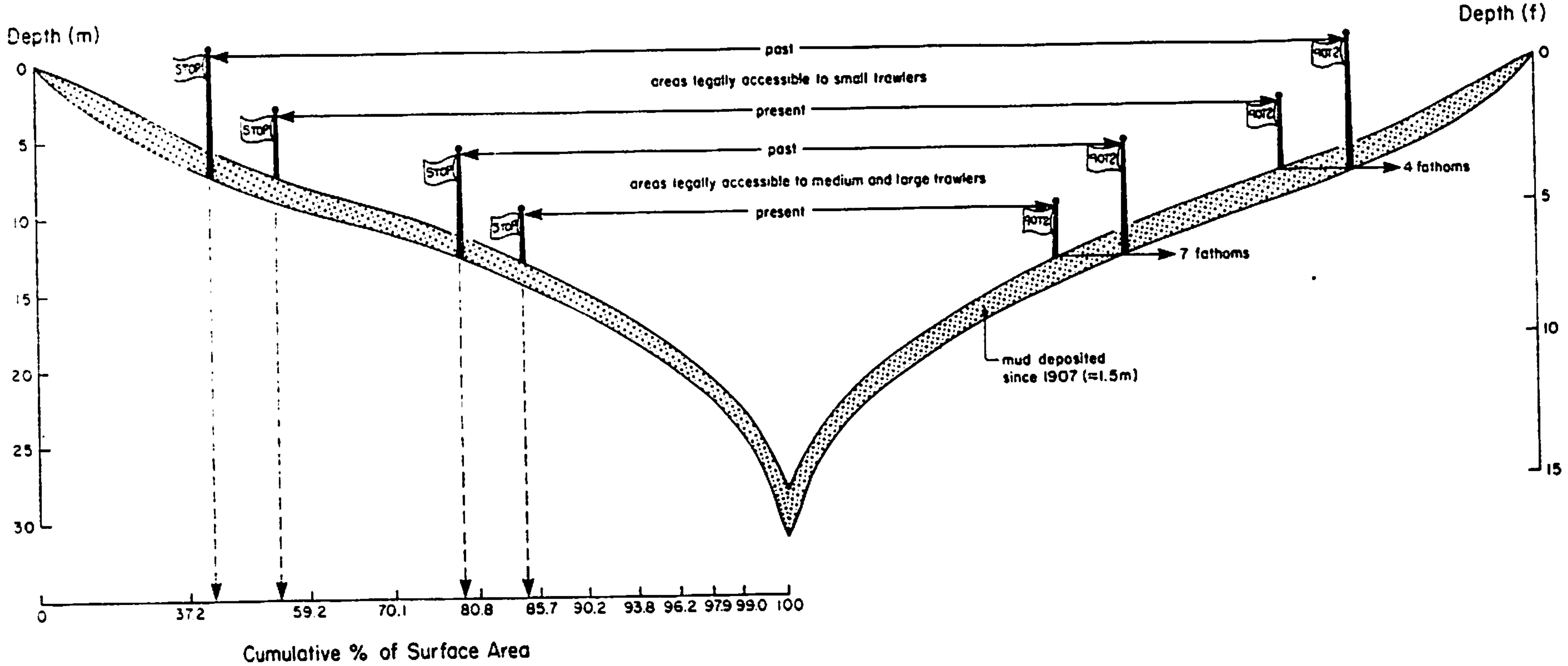

Fig. 8. Schematic representation of the surface area of San Miguel Bay legally accessible to trawlers below 3 GT (small tralwers) and above 3 GT (medium and large trawlers). Note impact siltation, which reduces the area legally accessible to trawlers of all kinds.

Discussion

The effects of the northeast monsoon on the fisheries of San Miguel Bay are rather straightforward and are demonstrated in several other papers included in this report. The estuarine conditions prevailing in the Bay have a major effect on the faunal composition and are one of the causes, for the very high productivity of the fishery. Both of these features are discussed in Pauly (this report). Emphasis here is on the implications of the fact that the Bay is becoming shallower with regard to the depth-related fishery regulations, and the deployment of passive and active fishing gears within the Bay.

Fig. 8 shows the surface area available to trawlers below and above 3 GT. As might be seen from Fig. 8, the siltation has the effect of noticeably reducing the area *legally* accessible to trawlers (both "municipal" and "commercial"); also the siltation has the effect of reducing the area *physically* accessible to trawlers (particularly those with deep draught). The accuracy of the values given in Fig. 8 should not be overestimated because all calculations are simply based on a uniform mud layer of 1.5 m superimposed onto the depth zonation extracted from the map. All that is intended here, indeed, is to point out the need for an accurate bathymetric survey of the whole Bay, as the basis to help settle the various claims on the Bay's water.

The siltation of the Bay in recent years seems to have affected gear deployment in that fixed gears, which were gradually replaced by mobile gears (especially trawls) in the sixties and early seventies are becoming popular again. Of course, increased fuel costs probably also contributed to this phenomenon.

Acknowledgements

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