MARINE BASELINE WATER QUALITY OF THE TRUST TERRITORY OF THE PACIFIC ISLANDS

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TRUST TERRITORY OF THE PACIFIC ISLANDS

ENVIRONMENTAL PROTECTION BOARD

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INTRODUCTION

The Trust Territory of the Pacific Islands (TTPI) was formed in 1947 and consisted of the Northern Mariana Islands and the districts of the Marshall Islands, Palau, Yap, Truk and Ponape. In the mid-seventies, Kosrae, which was part of the Ponape District, became a separate district, and, the Northern Marianas became a commonwealth of the United States; the TTPI was thereby established as the remaining six districts. The TTPI, which is scheduled to cease as a political entity in 1981, has at present fragmented into the Federated States of Micronesia (Yap, Truk, Ponape and Kosrae), the Constitutional Government of the Marshall Islands and the Government of the Republic of Palau (Figure 1). At the present time, Micronesia is in a transition period and the authors realize that any baseline levels of environmental water quality parameters established in this study (with reference to the pretransition TTPI) will have to be evaluated separately by the three new political entities in Micronesia.

The TTPI encompasses approximately a three million square mile area in the western Pacific Ocean (Micronesia). There are more than 2000 islands in the territory; these islands represent only 526 square miles of landed area (0.018% of the total area of the TTPI). The remote nature of these islands and the lack of analytical expertise on the local level account for the sparse data base quantifying the water quality in the marine environments surrounding these islands.

Water quality standards have been established by the Environmental Protection Board (EPB) of the TTPI based upon Territorial Public Law 4C-78 (1972) and the Federal Water Pollution Control Act P.L. 92-500 (1972). These standards have been established for various proposed beneficial uses of the water resources in the TTPI. These standards will remain arbitrary to Micronesia until they are validated by the collection of water quality data in the territory.

Islands from the six TTPI districts (Marshalls, Palau, Yap, Truk, Ponape and Kosrae) have been selected for study in order to quantify the existing background water quality for the district centers. Establishment of selected physical, chemical and bacteriological data bases in the territory will serve many functions. The baseline data will provide a basis for comparison against which future environmental impacts can be assessed. Comprehensive evaluation of modernization in Micronesia can only be accomplished on a local level. Monitoring programs must be developed in the offices of the district sanitarians. A secondary function of the baseline marine water quality data is that it would serve as a rationale for verification of the existing TTPI marine water quality standards. Deviations of observed water quality from the established standards might motivate changes (either increases or decreases) in marine water quality standards.

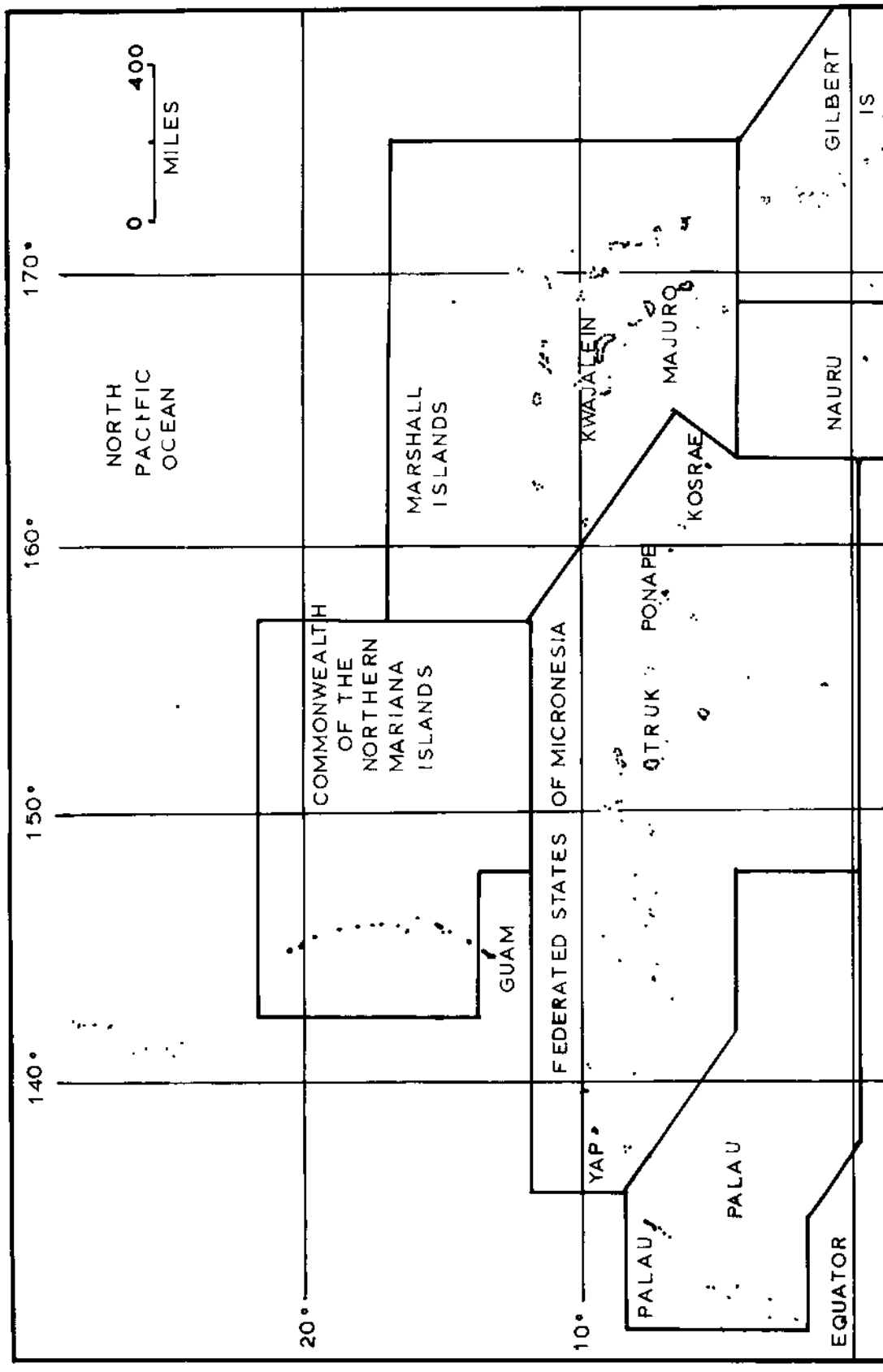

Figure 1. Micronesia and the new political boundaries of the TTPI.

OBJECTIVES

The baseline marine water quality study herein described consisted of the collection of data on three consecutive days in the following locations: Majuro Atoll; Ebeye and Gugeegue (Kwajalein Atoll); Koror (Palau); Yap Islands; Moen and Dublon (Truk Atoll); Ponape; Kosrae. Background water quality parameters quantified were: water temperature; salinity; turbidity; pH; dissolved oxygen; nitrogen and phosphorous nutrients; total and fecal coliform bacteria. These parameters were quantified on an islandwide basis as well as in the context of beneficial usage of the marine environments surrounding these islands.

Specific objectives were:

1. Comprehensive review of the literature summarizing existing water quality data in the TTPI.

2. Establishment of baseline water quality.

3. Validation of existing water quality standards utilizing territorial baseline water quality data.

4. Identification of specific areas which are in violation of water quality standards.

LITERATURE REVIEW

The data base quantifying the water quality in the marine environments surrounding the islands of the TTPI is sparse. Studies to date have included only marine biological surveys and research associated with the development of waste treatment facilities in the territory. Engineering consulting firms have been contracted through the EPB and the U. S. Department of the Navy, Officer in Charge of Construction (OICC, Marianas) to develop these waste treatment facilities plans. Researchers from Hawaii and the University of Guam Marine Laboratory have evaluated options for marine discharges of treated domestic sewage effluents. The water quality data from such studies are summarized in Table 1.

Physical, chemical and bacteriological parameters quantified included water temperature, turbidity, salinity, pH, dissolved oxygen (D.O.), total phosphorus (Total P), orthophosphate-phosphorus (PO_4-P), total Kjeldahl nitrogen (TKN), nitrate plus nitrite nitrogen ($[NO_3+NO_2]$-N) and coliform bacteria (total and fecal). In order to evaluate existing water quality data, the sites were grouped by

Table 1. Summary of Trust Territory of the Pacific Islands (TTPI) marine water quality data.

LOCATION	REFERENCE	TTPI CLASS	DATE	WATER TEMPERATURE °C $\bar{Y}$ (N)	TURBIDITY NTU $\bar{Y}$ (N)	SALINITY o/oo $\bar{Y}$ (N)	pH $\bar{Y}$ (N)	DISSOLVED OXYGEN mg/l $\bar{Y}$ (N)	TOTAL P mg/l $\bar{Y}$ (N)	PO_4-P mg/l $\bar{Y}$ (N)	TKN mg/l $\bar{Y}$ (N)	(NO_3+NO_2)-N mg/l $\bar{Y}$ (N)	TOTAL COLIFORM #/100ml $\bar{Y}$ (N)	FECAL COLIFORM #/100ml $\bar{Y}$ (N)
MAJURO	Mabbett (1972)	AA	Apr.1972					6.5 (7)			.10 (7)		7 (8)	10 (8)
		B	Apr. 1972					5.8 (4)			1.0 (4)		719 (7)	164 (8)
	Amesbury et al(1975)	AA	Aug.1975	30.7 (8)			7.51 (8)	6.6 (8)		.020 (6)		.003* (6)	<1 (8)	544 (8)
	Dames & Moore(1977)	AA	March 1977	28.0 (3)	1.7 (6)	34 (3)	8.24 (6)	6.8 (3)	.066 (6)		.07 (6)	.015 (6)		
		B	March 1977	27.0 (6)	.20 (6)	34 (6)	8.13 (6)	6.8 (6)	.139 (6)		.09 (6)	.007 (6)		
	M&E Pacific (1978)	AA	June 1978	28.3 (11)	.29(11)	33 (11)	8.13(11)	6.2 (11)	.013 (8)		.10 (11)	.003 (10)	0 (11)	0 (11)
		B	June 1978	28.4 (1)	.41 (1)	33 (1)	8.16 (1)	6.5 (1)			.14 (1)		0 (1)	0 (1)
EBEYE/ GUGEEGUE	Amesbury et al(1975)	B	Aug.1975	27.9 (8)			7.35 (8)	6.12 (8)		.013 (8)		.007* (8)		10596) (10)
	M&E Pacific (1978)	AA	Aug.1978		.20 (4)	34 (4)	8.31 (4)	6.0 (4)	.016 (4)		.12 (4)	.004 (4)	12 (4)	5 (4)
		B	Aug.1978		.25 (3)	34 (3)	8.23 (3)	5.7 (3)	.026 (3)		.14 (3)	.004 (3)	200 (7)	217 (3)
PALAU	Birkeland et al(1976)	B	Jan.1976	30.4 (8)		32 (8)		5.3 (8)		.004 (8)		.003* (7)	18 (8)	14 (8)
	Hawaii A.E. (1977)	AA	Dec.1977	29.6 (12)	.32(12)	33 (12)	8.12(12)	6.0 (12)	.008 (24)		.07 (24)	.004 (24)	<2 (12)	<2 (12)
	Randall et al (1978)	B	Nov.1977	30.0 (7)	.36 (7)	33 (7)				.004 (7)		.008* (7)		
YAP	Amesbury et al(1976)	B	Jan.1976	27.8 (16)		32 (16)		6.14(16)				.002* (7)	170 (7)	40 (14)
	Tsuda et al(1978)	B	March 1978	28.2 (16)		35 (16)	8.0 (6)	7.6 (6)		.002 (4)		.005 (4)		
		AA	March 1978	28.7 (13)		34 (12)	8.1 (6)	7.4 (6)		.001 (6)		.005 (6)		
TRUK	Tsuda et al(1975)	B	March 1975	28.4 (14)		33 (12)		5.78(12)		.007 (5)		.004* (5)		
	Amesbury et al(1977)	B	April 1977	29.0 (91)		34 (18)		6.52(91)		.005 (9)		.004* (9)		
	Clayshulte et al (1978)	B	Dec. 1977					7.15(24)		.005 (14)		.004 (14)		
	Brewer (1978)	B	March 1978	28.4 (16)		33 (16)		6.2 (16)						
		B	March 1978	28.7 (20)		34 (20)		6.0 (20)		.005 (6)	.10 (6)	.002 (6)	6 (18)	2 (18)
	Environmental Consultant (1978)	B	April 1978		.16 (6)				.021 (6)	.005 (6)	.08 (6)	.001 (6)		
		B	April 1978		.14 (6)				.018 (6)					
PONAPE	Tsuda et al (1974)	B	Aug. 1974	30.9 (9)		30 (9)		5.17 (8)					327 (10)	590 (10)
	Tenorio & Davis (1978)	AA	July 1977	29.0 (6)	.44 (4)	33 (6)	8.12 (4)	6.0 (6)	.016 (4)		.23 (4)	.021 (4)	78 (4)	6 (4)
		B	July 1977	30.1(12)	1.2 (8)	33 (12)	8.10 (8)	5.8 (12)	.018 (8)		.27 (8)	.013 (8)	196 (8)	28 (8)
KOSRAE	PAE Int'l (1979)	AA	Oct. 1978	32.6 (5)		30 (5)		7.0 (5)						
		B	Oct. 1978	31.1 (6)		32 (6)		4.7 (6)						

*NO_3-N data

$\bar{Y}$ = Mean

N = Number of samples

islands and TTPI coastal water classifications were assigned to each grouping. The designation of each TTPI class is presented in Table 2. TTPI water quality standards are listed in Table 3. The site descriptions, TTPI classifications, and the violations of water quality standards of the literature data base are discussed below.

The waste treatment facilities plan for Majuro (M & E Pacific and J. C. Tenorio and Associates) was completed in 1978. Studies by Mabbett (1972), Amesbury et al. (1975), Dames and Moore (1977) as well as those conducted by M & E Pacific account for the water quality data for Majuro Atoll. Class B waters from Majuro Atoll are the lagoon sites of the old and new Majuro dock areas; class AA waters include ocean sites off Dalap and Laura islands as well as lagoon sites not classified as B waters.

M & E Pacific and J. C. Tenorio and Associates completed facilities plans for Ebeye and Gugeegue islands in Kwajalein Atoll in 1978. Class B waters from these studies were lagoon waters in the vicinity of the Gugeegue and Ebeye docks as well as the proposed sewer outfall at the northern end of Ebeye island. Class AA water included ocean sites at Gugeegue and Ebeye as well as lagoon and ocean sites for Bijinkur island (an island between Ebeye and Gugeegue). Excessive concentrations of fecal coliform bacteria were noted for Ebeye (Amesbury et al., 1975); five of the ten stations were in violation of the TTPI fecal coliform standards (high and low measurements were 980,000/100 mℓ and 0/100 mℓ respectively). The samples gathered in 1978 (M & E Pacific and J. C. Tenorio & Associates) confirmed high levels of coliform bacteria in lagoon waters at the old sewer outfall (400 total coliform/100 mℓ and 50 fecal coliform/100 mℓ) and at the new sewer outfall at the northern end of Ebeye island (Too Numerous to Count, TNTC, total coliform and 600 fecal coliform/100 mℓ). The old outfall was not in violation of class B waters (fecal coliform <400/100 mℓ). The new outfall, however, did exceed the maximum allowable fecal coliform concentration indicating the presence of health hazards around the new outfall site. It is noted that the bacteriological data for Gugeegue class B waters (dock, lagoon) consisted of only a single 1978 sample: <2 total coliform/100 mℓ and <2 fecal coliform/100 mℓ.

Data on the Palau islands include a study by Birkeland et al. (1976) of the proposed sewer outfall off the Malakal island sewage treatment plant (class B waters). Hawaii Architects and Engineers completed a facilities plan for Palau which included water quality sampling stations on the ocean side of Koror and Arakabesan islands sufficiently out from shore to be considered AA waters. Koror harbor data was gathered by Randall et al. (1978) on the north side of Koror island east of Arakabesan island in B waters.

A wastewater facilities plan for the central Yap islands was developed by Lyon Associates (1978); the bacteriological data summarized in their report, although variable, indicated high total and

Table 2. Trust Territory of the Pacific Islands (TTPI) classification of coastal waters.

Class AA Waters

The uses to be protected in this class of waters are oceanographic research, the support and propagation of shellfish and other marine life, conservation of coral reefs and wilderness areas, compatible recreation, and aesthetic enjoyment.

It is the objective of this class of waters that they remain in as nearly their natural, pristine state as possible with an absolute minimum of pollution from any source. To the extent possible, the wilderness character of such areas shall be protected. No zones of mixing will be permitted in these waters.

The classification of any water area as Class AA shall not preclude other uses of such waters compatible with these objectives and in conformance with the standards applicable to them.

Class A Waters

The uses to be protected in this class of waters are recreational (including fishing, swimming, bathing, and other water-contact sports), aesthetic enjoyment, and the support and propagation of aquatic life.

It is the objective for this class of waters that their use for recreational purposes and aesthetic enjoyment not be limited in any way. Such waters shall be kept clean of any trash, solid materials or oils, and shall not act as receiving waters for any effluent which has not received the best degree of treatment or control practicable under existing technology and compatible with the standards established for this class.

Class B Waters

The uses to be protected in this class of waters are small boat harbors, commerical and industrial shipping, bait fishing, compatible recreation, the support and propagation of aquatic life, and aesthetic enjoyment.

It is the objective for this class of waters that discharges of any pollutant be controlled to the maximum degree possible and that sewage and industrial effluents receive the best degree of treatment control practicable under existing technology and compatible with the standards established for this class.

The Class B designation shall apply only to a limited area next to boat docking facilities in bays and harbors. The rest of the water area in such bay or harbor shall be Class A.

Table 3. Trust Territory of the Pacific Islands (TTPI) marine water quality standards

PARAMETER	UNITS	CLASS AA	CLASS A	CLASS B
Total Coliform	#/100mℓ	< 230		
Fecal Coliform	#/100mℓ		< 400	< 400
pH		Normal ± 0.2	Normal ± 0.2	Normal ± 0.5
		[6.5≤pH≤8.5]		
Total Nitrogen (TN)	mg/ℓ	≤0.40	≤0.75	≤1.50
		[Normal ± 10%]		
Total Phosphorus (TP)	mg/ℓ	≤0.025	≤0.050	≤0.100
		[Normal ± 10%]		
TN/TP	--	[Normal ± 10%]		
Dissolved Oxygen (D.O.)	mg/ℓ	≥6.0 or 75% of saturation, whichever is greater	≥5.0	≥4.5
Total Dissolved Solids (TDS)	mg/ℓ	[Normal ± 10%]		
Salinity	o/oo	[Normal ± 10%]		
Temperature	°C	[Normal ± 0.9]		
Turbidity	NTU, JTU	Normal + 5%	Normal ± 10%	Normal + 20%

fecal coliform concentrations in the Chamorro Bay and Tomil Harbor areas around the district center of Colonia. These data are not included in Table 1. Amesbury et al. (1976) evaluated proposed outfall sites off the Donitsch sewage treatment plant in Tomil Harbor (class B water). Tsuda et al. (1978) studied proposed sewage outfall sites off Balabat (class B water) and off Pelak (class AA water).

Sewage outfall sites on Moen Island (Truk Atoll) were studied at the Point Gabert wastewater outfall site (Tsuda et al., 1975). Amesbury et al. (1977) surveyed the area of a proposed tuna fishing complex at the old Japanese fuel dock on Dublon. Clayshulte et al. (1978) evaluated the site of a proposed fishery complex on Tol Island. The studies completed by Brewer (1978) consisted of sampling sites at Point Gabert and Sapuk peninsula (Moen) and the Tonof and fuel pier sites (Dublon). Environmental Consultants, Inc. (1978) studied the Moen site of Sapuk and the Dublon sites of Tonof and Sapun. The waters evaluated in the Truk Atoll were all TTPI class B.

Sewer outfall studies (Tsuda et al., 1974) were completed in the Tuanmokot Channel in Ponape in class B waters. Surface samples exceeded TTPI bacteriological standards in two of the ten sites analyzed (fecal coliform >400/100mℓ). Tenorio and Davis (1978) evaluated Ponape Harbor (class B waters) and the ocean area north of the harbor (class AA waters) in development of a facilities plan for Ponape.

The wastewater facilities plan for Kosrae (PAE International, 1979) included temperature, salinity and dissolved oxygen data for Lele Harbor (class B waters) and Malem (class AA waters).

The data presented in Table 1 and summarized in Tables 4 and 5 represent marine water quality parameters measured at different sites in the TTPI (six districts) for the period from April 1972 to October 1978. Due to the variables of site locations and time, no reliable statistic can be utilized to describe these data with any acceptable level of significance. The authors realize that geometric means and standard deviations are sometimes used to analyze water quality data (particularly bacteriological data). The arithmetic means listed in Tables 1, 4 and 5 are only utilized to indicate estimates of water quality conditions in the TTPI prior to the current marine baseline study.

Arithmetic means of the literature data for the physical and chemical parameters are presented in Table 4. These mean values are listed for each island group and for the territory as a whole using the data from Table 1. Total nitrogen concentrations (Total N) were calculated as the sum of total Kjeldahl nitrogen (TKN) and nitrate-nitrite nitrogen ($[NO_3+NO_2]$-N). Total nitrogen to total phosphorus ratios (TN/TP) were calculated as mass ratios.

Arithmetic means of the literature data for the bacteriological parameters are listed in Table 5. The mean values for total and fecal coliform concentrations are presented by island groups according to TTPI coastal water classifications because of the excessive differences between class AA and class B waters. The mean fecal coliform

Table 4. Arithmetic means of Trust Territory of the Pacific Islands (TTPI) literature data for physical and chemical parameters.

	WATER TEMPERATURE °C		TURBIDITY NTU		SALINITY o/oo		pH		DISSOLVED OXYGEN mg/ℓ		TOTAL P mg/ℓ		PO_4-P mg/ℓ		TKN mg/ℓ		(NO_3+NO_2)-N mg/ℓ		TOTAL N mg/ℓ		TN/TP MASS RATIO
	$\bar{Y}$	(N)	$\bar{Y}$	(N)	$\bar{Y}$	(N)	$\bar{Y}$	(N)	$\bar{Y}$	(N)	$\bar{Y}$	(N)	$\bar{Y}$	(N)	$\bar{Y}$	(N)	$\bar{Y}$	(N)	$\bar{Y}$	(N)	
MAJURO	28.7	(29)	.62	(24)	33	(21)	8.00	(32)	6.4	(40)	.067	(20)	.020	(6)	.20	(35)	.006	(28)	.21	--	3/1
EBEYE/GUGEEGUE	27.9	(8)	.22	(7)	34	(7)	7.78	(15)	6.0	(15)	.020	(7)	.011	(8)	.13	(7)	.006	(15)	.14	--	7/1
PALAU	29.9	(27)	.33	(19)	33	(27)	8.12	(12)	5.7	(20)	.008	(24)	.004	(15)	.07	(24)	.005	(38)	.08	--	10/1
YAP	28.2	(45)	--	--	34	(44)	8.05	(12)	6.7	(28)	--	--	.002	(17)	--	--	.001	(17)	--	--	--
MOEN, DUBLON, TOL	28.8	(141)	.35	(12)	34	(66)	--	--	6.46	(163)	.020	(12)	.005	(40)	.09	(12)	.003	(40)	.09	--	4/1
PONAPE	30.1	(27)	.94	(12)	32	(27)	8.11	(12)	5.7	(26)	.017	(12)	--	--	.26	(12)	.016	(12)	.28	--	16/1
KOSRAE	31.8	(11)	--	--	31	(11)	--	--	5.7	(11)	--	--	--	--	--	--	--	--	--	--	--
TTPI	28.9	(288)	.49	(74)	33	(203)	8.00	(83)	6.3	(303)	.028	(75)	.006	(86)	.15	(90)	.005	(150)	.16	--	6/1

$\bar{Y}$ = Mean
N = Number of samples

Table 5. Arithmetic means of Trust Territory of the Pacific Islands (TTPI) literature data for bacteriological parameters.

Location	Total Coliform #/100mℓ				Fecal Coliform #/100mℓ			
	AA		B		AA		B	
	$\bar{\bar{Y}}$	(N)	$\bar{Y}$	(N)	$\bar{\bar{Y}}$	(N)	$\bar{Y}$	(N)
MAJURO	2	(27)	629	(8)	164	(27)	322	(9)
EBEYE	40	(1)	400	(1)	16	(1)	<u>88355</u>	(12)
GUGEEGUE/BIJINKUR	2	(3)	1	(1)	1	(3)	1	(1)
PALAU	1	(12)	18	(8)	1	(12)	14	(8)
YAP	--	--	170	(14)	--	--	40	(14)
TRUK	--	--	6	(18)	--	--	2	(18)
PONAPE	28	(4)	268	(18)	6	(4)	341	(18)
TTPI	5	47	190	68	95	47	<u>13375</u>	80
							143*	68

*TTPI mean B water omitting Ebeye

Underscored data represent TTPI violations

$\bar{\bar{Y}}$ = Mean

N = Number of samples

values (class B waters) for Ebeye and the TTPI were 88,355/100 mℓ and 13,375/100 mℓ respectively; these values far exceed the TTPI class B standards for fecal coliform (<400/100 mℓ). It is noted that territorial class B waters have a mean fecal coliform value of 143/100 mℓ if the Ebeye data were omitted.

The Water Resources Research Center (WRRC) of the University of Guam is currently monitoring the progress of the airport expansion project on Moen Island, Truk Atoll (Clayshulte et al., 1979; WRRC report pending). In order to evaluate the environmental impact of the expansion of the airport, water quality sampling stations have been continuously monitored on a monthly basis since June 2, 1978. A summary of the data for the control station (class AA) is presented in Table 6. Both surface and bottom water quality data are summarized to emphasize the fact that no difference exists in the water quality column at this station. The water quality data summarized in Tables 4, 5 and 6 will be utilized in conjunction with the data gathered in this research in order to establish the TTPI natural conditions (baseline) of water quality in the marine environments surrounding the district centers of Micronesia.

Eutrophication in marine environments is a process whereby the waters in bays and in areas inside fringing reefs age through accumulation of nutrients in these waters. Man's usage of these marine environments as well as increased human activity on the islands themselves will accelerate this process through further addition of nutrients. Eutrophication manifests itself through increased phytoplankton populations with eventual dominance of these populations by the nuisance blue-green algae.

The marine environment surrounding the islands of Micronesia represents a complex physical, chemical and biological system. The concentrations of nutrients in these environments will regulate the levels of primary productivity (phytoplankton, macrophytic algae and corals). In order to quantify the extent of pollution in the waters of the TTPI, a portion of this primary productivity will be analyzed (phytoplankton productivity). Marine algal bioassay techniques (U.S.E.P.A., 1974) are utilized to assess the nutrient(s) limiting phytoplankton growth. Algal assays are based upon Liebig's law of the minimum (Browne, 1942): biomass production is related to the available concentration of the limiting nutrient. Typical marine phytoplankton have been characterized stoichiometrically as 106C:16N:1P (Redfield et al., 1963). Classically, nitrogen (N) and phosphorus (P) are considered to be the primary limiting nutrients.

Algal growth responses between 0.0025 and 0.050 mgP/ℓ and 0.010 and 1.000 mgN/ℓ have been extensively examined (U.S.E.P.A., 1974) utilizing the green alga *Dunaliella tertiolecta*. Biomass yields in terms of milligrams dry weight per microgram nutrient have been established: 1.08 mg dry wt./μg PO_4-P; 0.03 mg dry wt./μg NO_3-N; 0.08 mg dry wt./μg NH_3-N. This yeld data can be utilized together

Table 6. Physical and chemical characteristics of lagoon water at the control monitoring station for the airport expansion project on Moen Island, Truk Lagoon.

DATE	WATER TEMPERATURE °C		TURBIDITY NTU		SALINITY o/oo		pH		DISSOLVED OXYGEN mg/ℓ		TOTAL P mg/ℓ		PO_4-P mg/ℓ		TKN mg/ℓ	
	Surface	Bottom	Surface	Bottom	Surface	Bottom	Surface	Bottom	Surface	Bottom	Surface	Bottom	Surface	Bottom	Surface	Bottom
1978																
June 2	--	29.3	--	.28	--	33	--	8.12	--	6.28	--	.021	--	--	--	.11
June 26	29.5	29.7	.27	.18	34	34	8.22	8.22	6.36	6.19	--	.012	--	--	--	.03
July 7	29.8	29.6	--	.30	33	33	8.28	8.28	7.31	6.65	--	.009	--	--	--	.02
July 21	29.1	29.1	.23	.20	34	34	8.21	8.19	6.60	5.87	--	.012	--	--	--	.09
Aug. 4	29.9	29.9	.22	.24	35	35	8.28	8.28	6.15	6.15	--	.011	--	--	--	.02
Sept. 1	30.5	29.8	.25	.30	34	34	8.29	8.30	7.31	5.57	.014	.013	--	--	.06	.05
Oct. 4	29.2	29.8	.66	.68	33	34	--	--	6.15	6.73	.004	.006	--	--	.03	.12
Nov. 2	30.1	29.8	.77	.77	34	34	8.15	8.10	7.89	6.90	.009	.008	--	--	.08	.08
Dec. 7	29.2	29.2	.30	.30	34	33	8.21	8.21	6.73	6.48	.008	.008	--	--	.12	.12
1979																
Jan. 9	28.6	28.4	.45	.33	32	32	8.30	8.28	6.90	7.06	.005	.008	--	--	.10	.12
Feb. 6	27.9	28.0	.25	.28	33	33	8.20	8.21	6.98	7.15	.006	.010	--	--	<.01	<.01
March 6	27.8	--	.25	--	34	--	8.30	--	7.15	--	.003	.013	--	--	.14	--
April 3	28.2	28.0	.29	.29	34	34	8.32	8.32	6.64	6.97	.006	.004	--	--	.20	.13
May 7	28.2	28.2	.32	.27	34	34	8.22	8.22	6.52	6.52	.007	.007	--	.000	.12	.13
June 1	28.9	28.8	.37	.34	34	34	8.29	8.29	6.50	6.64	.003	.003	--	.003	.33	--
July 6	28.9	28.7	.25	.28	34	35	8.20	8.19	6.72	6.38	.003	.000	--	.004	.11	.19
Aug. 9	28.8	28.8	.42	.48	34	34	8.19	8.19	6.73	6.73	.024	.022	--	.028	.20	.10
Sept. 5	29.2	29.4	.47	.44	34	34	8.22	8.24	6.19	5.94	.008	.009	--	.007	.10	.76
Oct. 2	29.3	29.2	.65	.60	34	34	8.28	8.28	--	6.32	--	.021	--	--	.12	.08
Oct. 30	--	--	.58	.58	33	33	8.20	8.20	6.45	6.94	.000	.080	--	--	.01	.12
Dec. 7	28.0	28.3	1.2	1.0	34	34	8.20	8.20	6.80	6.94	.012	.009	--	--	.35	.18
1980																
Jan. 3	28.3	28.3	1.0	.43	34	35	8.20	8.20	7.56	5.53	--	.004	--	--	--	.18
Feb. 1	28.0	27.8	.23	.28	34	34	8.20	8.20	6.79	6.61	.005	.004	--	--	.09	.07
$\bar{Y} \pm S$	28.9±.8	28.9±.7	.44±.3	.40±.2	34±.6	34±.7	8.24±.05	8.22±.05	6.78±.46	6.61±.87	.007±.006	.013±.016	.008±.011		.13±.10	.13±.15
N	21	21	21	22	22	22	21	21	21	22	16	23	5		17	21

$\bar{Y}$ = Arithmetic mean.
S = Standard deviation
N = Number of samples.

with TTPI baseline concentrations of orthophosphate phosphorus (PO_4-P), nitrate nitrogen (NO_3-N) and ammonia nitrogen (NH_3-N) to estimate the yield of phytoplankton biomass and to identify the limiting nutrient in TTPI waters.

Specht (1975) studied the variation of algal biomass production and nutrient limitation in marine water samples under laboratory conditions outlined in the Marine Algal Assay Procedure, MAAP (U.S.E.P.A., 1974). Nitrogen and phosphorus algal growth rate limitation was evaluated in this study utilizing total soluble inorganic nitrogen (TSIN) and orthophosphate phosphorus (PO_4-P); the results of this study are presented in Figure 2. These data are representative of marine environments in general and the predominant limiting nutrient was nitrogen. It is noted that TSIN represents the sum of the inorganic constituents of NO_3-N, nitrite nitrogen (NO_2-N) and NH_3-N. The maximum (TSIN)/(PO_4-P) mass ratio where nitrogen was the limiting nutrient was 15/1; therefore, for the purpose of this TTPI baseline water quality study, any marine waters with inorganic nitrogen to phosphorus mass ratios greater than 15/1 will be assumed to be phosphorus limited waters and those marine waters with ratios of less than 15/1 will be assumed to be nitrogen limited. Algal bioassay literature offers two distinct estimates of limiting nutrient: one based upon yields and the second based upon (TSIN)/(PO_4-P) ratios.

MATERIALS AND METHODS

Water quality parameters were measured at preselected sites in each of the six districts. The sites were based on the TTPI classification of coastal water uses (Table 2). The water quality parameters measured were: physical (temperature, salinity, turbidity, pH), chemical (dissolved oxygen, orthophosphate phosphorus, total phosphorus and total nitrogen) and bacteriological (total and fecal coliforms). Total nitrogen was assessed by measuring the nitrogen components of total Kjeldahl nitrogen (TKN = organic nitrogen + ammonia nitrogen), nitrate-nitrite and ammonia nitrogen. Table 7 presents the methods of analysis used for each parameter.

Water samples were collected either by boat or walk-in collection. Special care was taken during walk-in sampling to avoid contamination of the water mass from disrupted bottom sediments and sampling personnel. Samples were taken toward the oncoming water mass. The direction of water movement was determined with fluorescein dye tracks.

Secchi disc measurements were taken at those sites where visibility through the water column was less than the station depth. Secchi disc determinations quantify the depth of visibility. Light

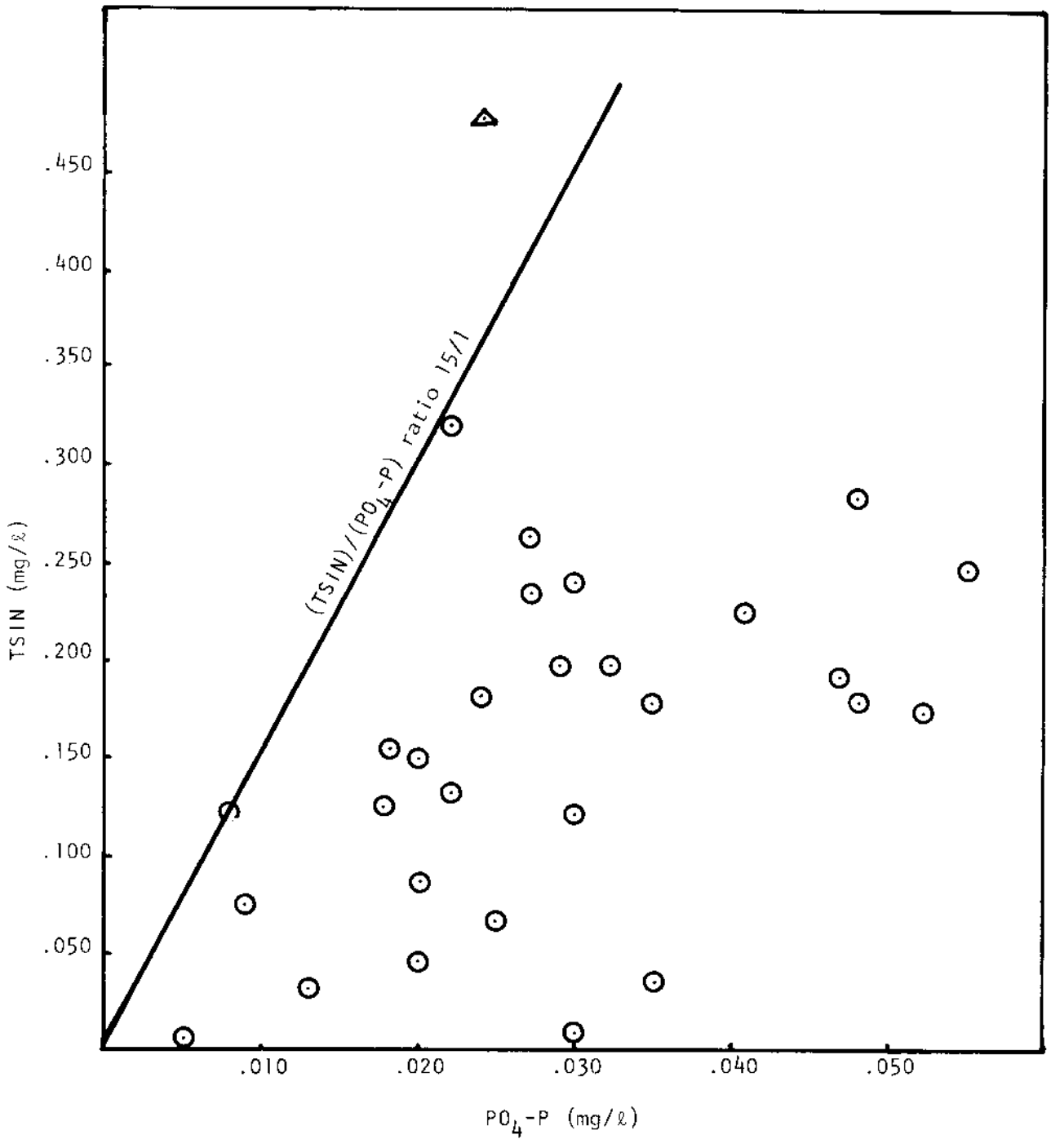

Figure 2. Nitrogen limited (O) and phosphorus limited (Δ) marine algal bioassays from Specht, 1975.

Table 7. Physical, chemical and bacteriological parameters and methods used in analyses for baseline study. All standard methods of analyses were performed according to the 13th edition (1971).

PARAMETER	METHOD	REFERENCE
PHYSICAL		
Temperature	20-50°C Mercury Thermometer	Standard Methods
Salinity (Refractometer)	Optical Refractometer, direct reading	--
Turbidity	Nephelometer (NTU)	Standard Methods
pH	pH specific ion meter/combination electrode	Standard Methods
CHEMICAL		
Dissolved Oxygen	Azide modified Winkler titration	Standard Methods
Total Phosphorus	Persulfate Digestion/Ascorbic Acid Reduction	Standard Methods
Orthophosphate-phosphorus	Ascorbic Acid Reduction	(Strickland and Parson, 1971)
Nitrate-nitrite nitrogen	Cadmium Reduction	(Strickland and Parson, 1971)
Ammonia nitrogen	Indophenol	(Solorzano, 1969)
Total Kjeldahl Nitrogen	Digestion/Distillation/Nesslerization	Standard Methods
BACTERIOLOGICAL		
Total and Fecal Coliform Bacteria	Membrane Filtration	Standard Methods

from the surface (sunlight) penetrates the water and is reflected back up to the surface off a white circular plate (Secchi disc). Secchi disc depth was determined as the average point of disappearance for the descending and ascending disc.

Water samples were field collected with a Van Dorn sampler. Samples were taken from a depth of one meter (m) when possible with the sampler in a vertical position. The sites that were less than 1 m deep were sampled with the Van Dorn sampler in a horizontal position in the midwater column. Salinity and temperature were measured at the site from the Van Dorn sampler. Salinity was measured with a calibrated refractometer and temperature by mercury thermometer (20-50°C). Dissolved oxygen samples were collected in special 300 mℓ bottles, fixed at the site and kept in a covered transfer box. Coliform bacteria samples were collected in either presterilized plastic twirl bags or autoclaved wide mouth bottles. Water samples for dissolved oxygen, coliform bacteria, turbidity and pH were taken to laboratories at the district centers for analyses. Samples for the determination of the phosphorus and nitrogen components were collected in precleaned bottles for shipment to the Water Resources laboratory for analyses. The orthophosphate phosphorus, nitrate-nitrite and ammonia nitrogen samples were filtered through a .45μ millipore filter prior to freezing. The total phosphorus/TKN samples and filtered samples were frozen at the district centers as a means of preservation.

Total and fecal coliform were measured with the membrane filter technique. Bacteria samples were kept on ice in the field and analyzed within eight hours of collection. Bacteria samples were taken from surface waters at the Marshall, Yap and Palau sites and subsurface at the Truk, Ponape and Kosrae sites. Nephelometry was used to obtain turbidity data. A Hach portable turbidimeter was used to measure turbidity levels. Dissolved oxygen was determined with the azide modification of the Winkler titration method. pH samples were measured with a portable specific ion meter and combination pH electrode.

The chemical parameters were analyzed in accordance with *Standard methods for the examination of water and wastewater* (1975). Techniques presented in *A practical handbook for seawater analysis* (Strickland and Parsons, 1971) were used to determine orthophosphate phosphorus and nitrate-nitrite nitrogen. The indophenol technique (Solorzano, 1969) was used to determine ammonia nitrogen.

Meteorological Data

Weather data including wind speed and direction, air temperature, water temperature, 24-hour sunshine, barometric pressure, and 24-hour precipitation were obtained from the U. S. Department of Commerce National Weather Stations at the district centers. The 24-hour average for the meteorological parameters is presented in Table 8.

Table 8. Summary of meteorological data.

DISTRICT	DATE	WIND Dir.	WIND Speed (Kts)	AIR TEMPERATURE (°F)	AIR TEMPERATURE (°C)	BAROMETRIC PRESSURE (in Hg)	RAIN 24-Hr (in)	SUNSHINE 24-Hr (min.)	SEAWATER TEMPERATURE (°F)	SEAWATER TEMPERATURE (°C)
MARSHALL	1979									
UAITRO	Sept. 20	E	12	82	27.2	--	.29	496	--	--
	Sept. 21	E	7	82	27.2	--	.61	328	--	--
	Sept. 22	E	6	81	27.2	--	.09	404	--	--
	Sept. 23	E	13	83	28.4	--	T*	537	--	--
KWAJALEIN										
	Nov. 26	SSW	15	83	28.4	--	.04	--	85.2	29.5
	Nov. 27	SE	13	83	28.4	--	T*	--	85.4	29.6
	Nov. 28	NNE	13	82	27.7	--	1.05	--	85.4	29.6
	Nov. 29	NNE	23	81	27.2	--	1.50	--	85.2	29.5
MAJRO										
ROBOR	Dec. 18	NE	5	81	27.2	--	.44	74	--	--
	Dec. 19	NE	3	81	27.2	--	.15	44	--	--
	Dec. 20	E	3	82	27.7	--	.34	265	--	--
	Dec. 21	E	4	83	--	--	.21	593	--	--
YAP	Dec. 23	NE	10	80	26.6	--	2.02	198	--	--
	Dec. 24	NE	6	76	24.4	--	1.61	0	--	--
	Dec. 25	NE	0	81	27.2	--	0	302	--	--
	Dec. 26	E	7	81	27.2	--	.11	534	--	--
	Dec. 27	NE	6	79	26.1	--	.12	479	--	--
	1982									
TRUK										
MOEN	Jan. 1	ENE	8	80	26.6	29.75	1.16	168	82.6	28.1
	Jan. 2	ENE	7	80	26.6	29.75	1.12	436	82.6	28.1
	Jan. 3	ENE	6	81	27.2	29.70	1.13	325	82.8	28.2
	Jan. 4	ENE	6	81	27.2	29.70	.01	556	83.3	28.5
PONAPE	Jan. 5	ESE	4	82	27.7	29.59	.06	157	--	--
	Jan. 6	SE	3	80	26.6	29.63	1.17	111	--	--
	Jan. 7	E	3	80	26.6	29.57	1.72	19	--	--
	Jan. 10	ENE	5	78	25.5	29.65	.69	2	--	--
KOSRAE	Jan. 12	NE	7	86	30.0	29.89	.15	--	--	--
	Jan. 13	ENE	11	87	30.5	29.80	0	--	--	--
	Jan. 14	NE	8	83	28.4	29.82	T*	--	--	--
	Jan. 15	NE	5	84	28.9	29.77	.21	--	--	--

T Trace, <.1 inch

RESULTS

Trust Territory of the Pacific Islands (TTPI) water quality standards are listed in Table 3. Standards for water temperature, turbidity, salinity, and total nitrogen/total phosphorus ratios (TN/TP) are dependent upon the establishment of the natural (baseline) water quality conditions for these parameters. Violations of standards for these parameters can only be identified when these normal conditions have been quantified; the primary objective of this research is to establish such natural conditions. The data are therefore presented separately for each island group in the territory. These data are summarized according to islands and TTPI classifications. The summarized data from this research are evaluated on the basis of arithmetic means and ranges of values for each parameter studied. The data were plotted on probability paper and median values were determined for each parameter. Baseline water quality for the territory was determined from these mean and median values for each TTPI class (AA, A, and B). Phytoplankton growth rate limiting nutrient was identified and inorganic N/P mass ratios (total soluble inorganic nitrogen/orthophosphate phosphorus) were determined. Standards have been established for TN, TP, total and fecal coliform bacteria. Minimum levels of dissolved oxygen (D.O.) and ranges for pH are also identified in the TTPI water quality standards. Violations for these parameters are discussed for each island group.

Majuro Atoll

Water quality samples were gathered from the lagoon and ocean waters surrounding the Darrit-Uliga-Dalap and Laura areas of Majuro Atoll (Figure 3) on November 21-23, 1979. The ten sites sampled are represented in Figures 4 and 5. Four sites were sampled by boat (2, 3, 6 and 7) and the remaining six were sampled by wading out from shore. The sampling sites were:

1. DARRIT OCEAN: 50 m offshore between house and radio tower.

2. DARRIT LAGOON; 50 m out from two radio towers, approximately one quarter mile north of high school.

3. ULIGA LAGOON; north of Old Majuro Dock; 50 m offshore; 5 houses, 4 benjos on shoreline; children observed swimming near shore.

4. ULIGA OCEAN; 50 m offshore at hospital; algal mat on rocks; clumps of floating debris (algae).

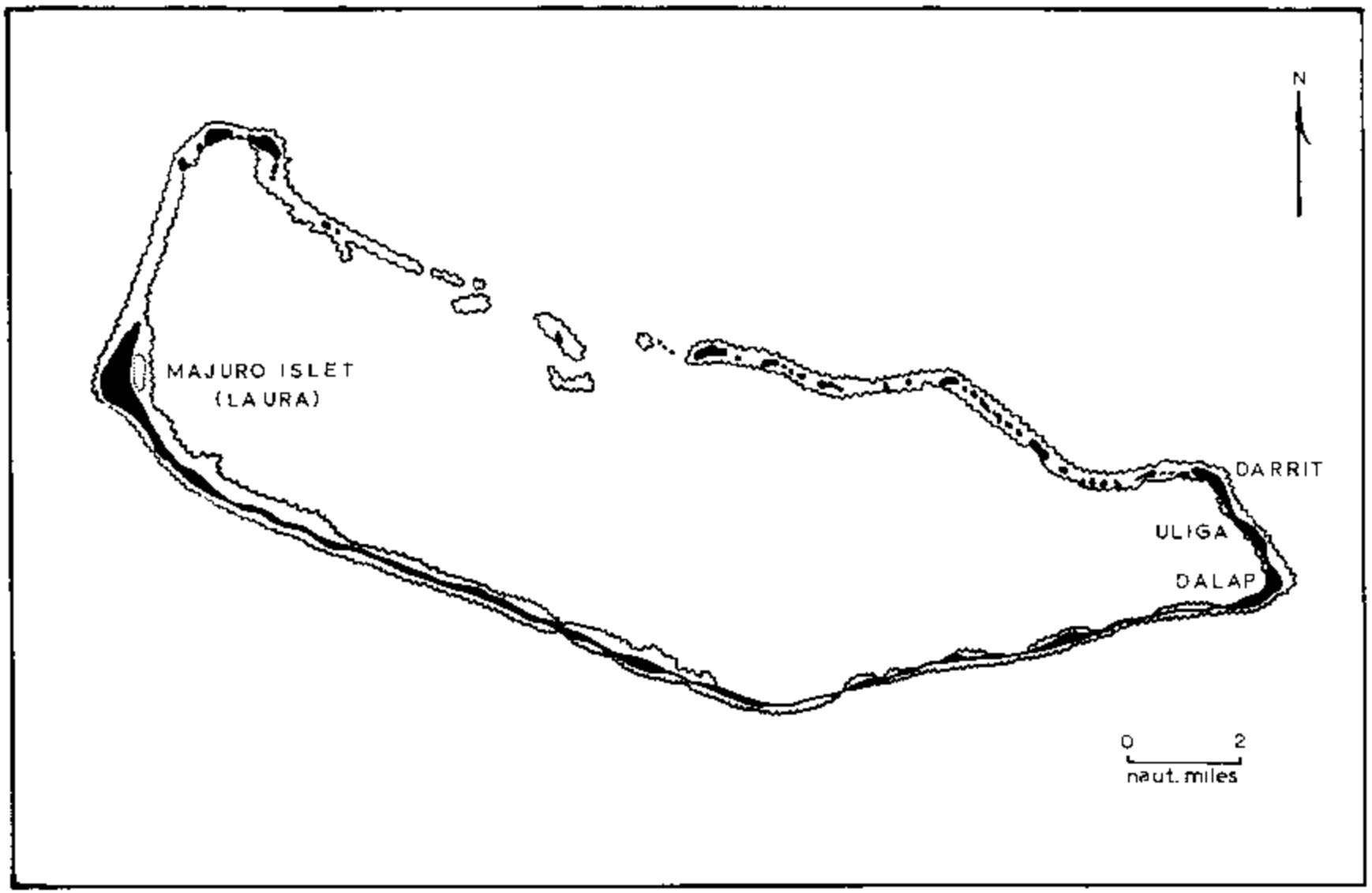

Figure 3. Sampled islets in Majuro Atoll.

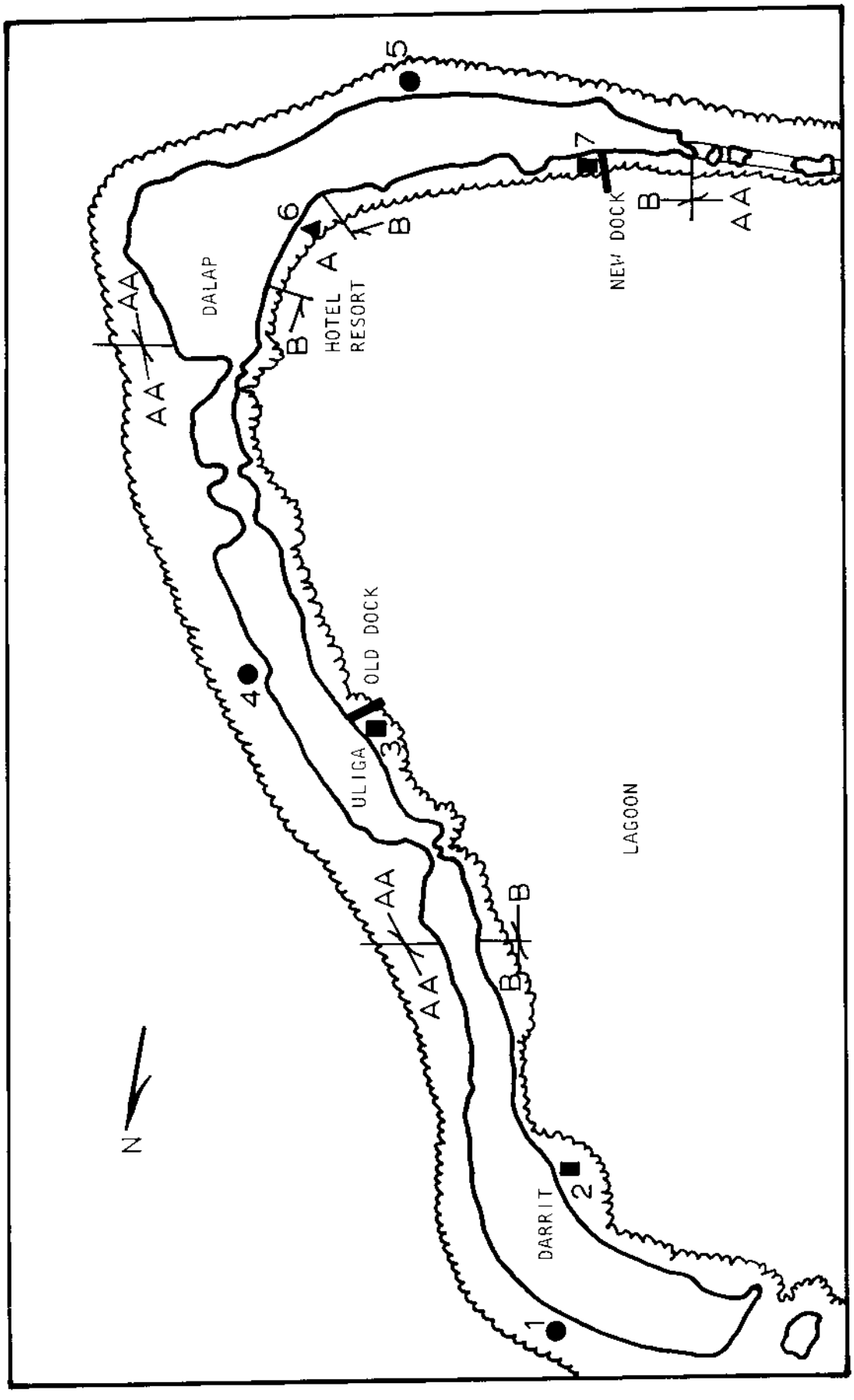

Figure 4. Sampling sites 1-7 in DUD area, Majuro Atoll. The circles are AA waters, the triangle is A water and squares are B waters.

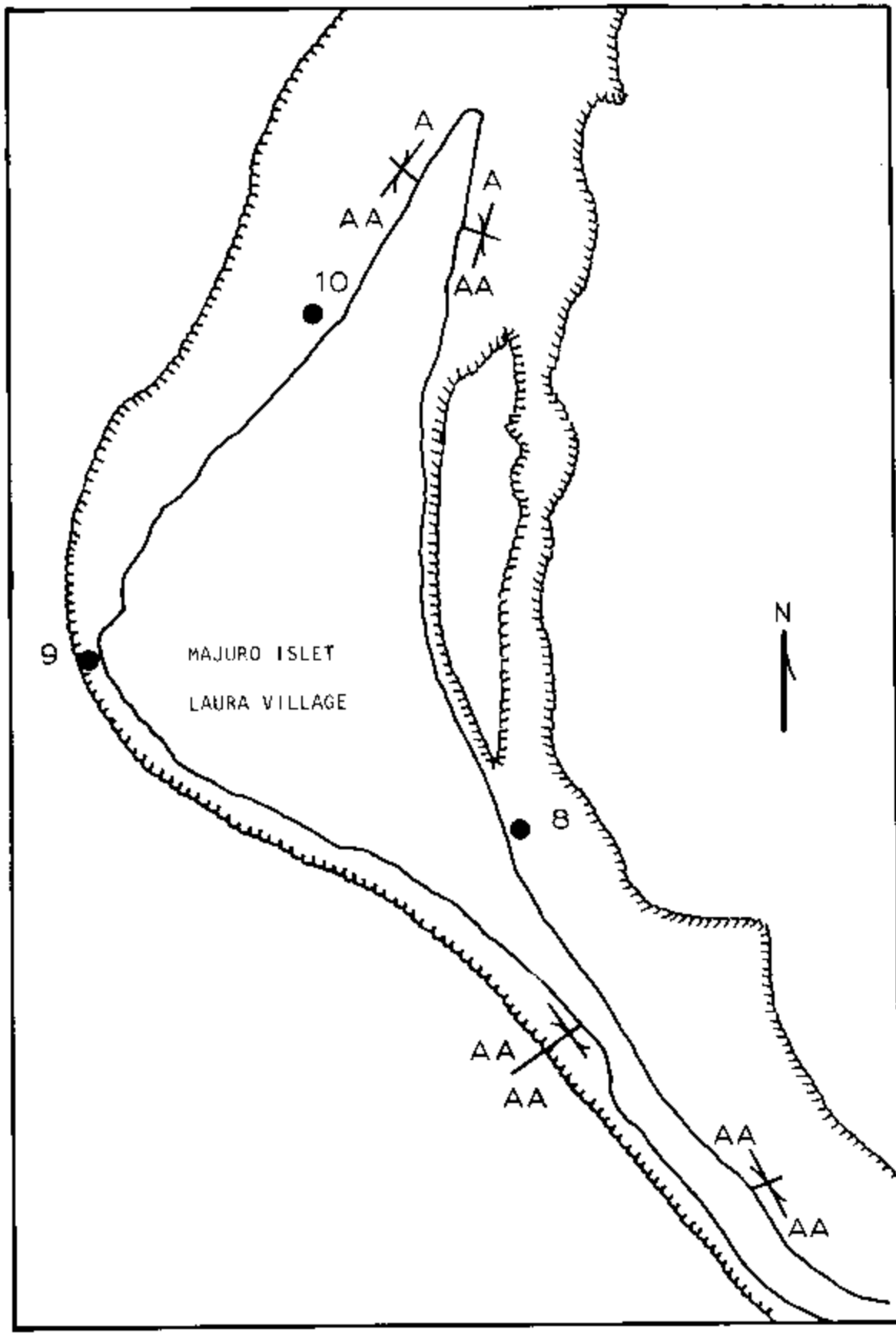

Figure 5. Sampling sites 8, 9 and 10 at Laura Village, Majuro Islet. The circles are AA waters.

5. DALAP OCEAN; 30 m offshore at Dalap Elementary School.

6. DALAP LAGOON; 50 m offshore at Eastern Gateway Hotel Restaurant.

7. DALAP LAGOON; 50 m off the middle of the New Majuro Dock.

8. LAURA LAGOON; 20 m offshore; floating debris (coconuts, white filamentous masses); several pigs observed in area. Site was out from highway approximately 100 m toward Laura from 'miles 28 Rita 28' road sign.

9. LAURA OCEAN; 30 m offshore at road to westernmost tip of Laura.

10. LAURA OCEAN; 20 m offshore at northernmost house on Laura.

Sampling time, tide, depth of sampling site, Secchi depth and water current data are presented in Table 9. Changes in station depth of site 7 beyond those quantified by changing tides were attributed to boat drift. On November 23, a Secchi depth determination for site 7 was taken (10 m). The waters in this area were observed to have a green color, indicating the presence of marine phytoplankton (not quantified).

Physical, chemical (D.O.) and bacteriological data are presented in Table 10. Problems with dissolved oxygen (D.O.) reagents accounted for loss of D.O. data on November 21st. Violations of pH standard ranges were observed at site 9 (Laura, ocean) for the November 22 and 23 samples. However, the average pH value for the station was 8.47, which is within the permissible limit for pH. Class AA bacteriological violations (total coliform >230/100 mℓ) were quantified at sites 1 and 4. At site 1 (Darrit, ocean), and to a lesser extent at site 4 (Uliga, ocean off hospital), the high coliform counts were concluded to occur because the local people utilized the rocky area along the shore line as toilet facilities.

Nitrogen and phosphorus data for Majuro are listed in Table 11. Total P concentrations were ≤0.011 mgP/ℓ at all stations; this indicates the marine waters surrounding Majuro Atoll are of good quality. Total N concentrations were in violation of TTPI class AA standards for sites 4 (Uliga, ocean, hospital) and 5 (Dalap, ocean, elementary school) on November 22nd. These total N values were concluded to be due to laboratory experimental error inherent in the TKN analysis. The average total N values for sites 4 and 5 excluding the November 22nd samples were 0.08 and 0.16 mgN/ℓ respectively, values which are less than TTPI standard of 0.40 mgN/ℓ.

Table 9. Physical characteristics at Mojave sampling sites.

	SITE	TTFI CLASS	SAMPLING TIME			TIDE			DEPTH OF SITE (m)			SECCHI (m)			CURRENT DIRECTION (RELATIVE VELOCITY)		
MARSHALL	1	AA	1435	1720	1750	SR	NEAP	SR	1	1	1				W	WNW	WNW
MOJAVE	2	B	1150	0900	0920	SR	SF	SF	2.5	3.2	3.7				W	W	WSW
November 21 23	3	B	1217	0935	0936	SR	SF	SF	2.2	3.2	3.7				-	(W)	NW	SE
1979	4	AA	1655	1745	1805	SR	NEAP	NEAP	1.5	1	1.5				SSE	SSE	SSE
	5	AA	1825	1615	1705	SF	SR	SR	1.7	1.7	1				ESE	E	SW
	6	A	1236	0932	0948	SR	SF	SF	3	1.7	3.5				ENE	ESE	WSW
	7	B	1255	0948	1000	SR	SF	SF	10	17	16.6	--	--	10	WSW	SE	SE
	8	AA	1725	1510	1550	SF	SR	SR	1.7	1.5	1.5				SE	-	(W)	SSW
	9	AA	1700	1440	1520	SF	SR	SR	1.7	0.7	0.5				NNW	SW	SW
	10	AA	1640	1415	1450	NEAP	SR	SR	1.7	1	1				ENE	ENE	WSW

TIDE:
SR - Strong rising
SF - Strong falling
NEAP - 30 min. before and after tide change

CURRENT VELOCITY:
(W) - Weak current

Table 10. Physical and bacteriological characteristics of water at Majuro sampling sites.

STATION	TTPI CLASS	WATER TEMPERATURE °C			TURBIDITY NTU			pH			DISSOLVED OXYGEN mg/ℓ			SALINITY o/oo			TOTAL COLIFORM #/100 mℓ			FECAL COLIFORM #/100 mℓ		
1	AA	29.8	29.3	29.7	0.4	0.2	0.6	8.60	8.15	8.15	--	6.42	6.66	31	34	33	218	2260	2300	184	20	690
2	B	29.8	29.0	29.8	0.3	0.2	0.3	8.25	8.18	8.02	--	5.93	5.60	34	32	32	5	11	11	1	3	7
3	B	29.8	29.3	30.0	0.3	0.2	0.3	8.30	8.18	8.12	--	5.86	6.17	34	33	34	3	11	5	1	3	2
4	AA	29.4	29.5	30.0	0.4	0.3	0.6	8.40	8.30	8.12	--	6.32	6.34	32	34	34	17	247	830	1	70	130
5	AA	29.3	30.0	30.1	0.2	0.2	0.6	8.20	8.18	8.25	--	6.66	6.76	32	33	34	39	9	11	13	2	260
6	A	29.5	29.2	29.8	0.3	0.2	0.3	8.10	8.10	8.15	--	5.66	6.06	34	33	34	1	8	2	0	4	1
7	B	29.5	29.3	29.4	0.3	0.3	0.3	8.10	8.10	8.10	--	6.05	6.28	33	34	33	0	1	6	0	0	5
8	AA	28.1	30.3	30.8	0.6	0.8	2.7	7.77	8.30	8.20	--	12.87	9.97	32	32	32	104	10	<10	124	10	<10
9	AA	29.0	33.6	33.6	0.4	0.3	0.4	8.00	8.80	8.60	--	9.82	10.14	32	32	32	56	2	0	18	0	0
10	AA	29.0	32.6	31.7	0.6	0.4	0.4	8.00	8.50	8.35	--	12.99	8.44	32	32	33	54	<10	0	81	<5	0

Underscored data represents violations of TTPI standards.

Table 11. Chemical characteristics of water at Majuro sampling sites.

STATION	TTPI CLASS	PO_4-P mg/ℓ			TOTAL P mg/ℓ *			$(NO_3 + NO_2)$-N mg/ℓ			NH_3-N mg/ℓ			TKN mg/ℓ			TOTAL N mg/ℓ **				ISIN*** mg/ℓ		
1	AA	.006	.006	.006	.025	.010	.006	.006	.007	.010	.004	.020	.020	<.010	.17	.02	.02	.40	.18	.03	.02	.022	.030	.010
2	B	.007	.003	.014	.100	.010	.008	.014	.012	.004	.012	<.010	<.010	.014	.05	<.01	.01	1.50	.06	<.01	.02	.017	<.010	.026
3	B	.005	.005	.004	.100	.011	.009	.006	.021	.014	.007	.020	.019	.020	.15	.50	<.01	1.50	.17	.51	.01	.041	.033	.027
4	AA	.004	.006	.006	.025	.006	.006	.006	.008	.007	.068	.019	.015	<.010	.07	.01	.02	.40	.08	.62	.09	.027	.022	.024
5	AA	.004	.005	.006	.025	.005	.006	.006	.007	.010	.005	.019	<.010	.013	.08	1.19	.20	.40	.09	1.20	.21	.026	.015	.018
6	A	.004	.004	.004	.050	.008	.008	.007	.024	.010	.003	.027	<.010	.011	.01	.23	.11	.75	.05	.24	.11	.026	.015	.014
7	B	.005	.005	.004	.100	.008	.006	.008	.013	.008	.003	.035	.020	.018	.01	.03	.16	1.50	.04	.04	.16	.038	.028	.021
8	AA	.003	.003	.006	.025	.005	.005	.015	.007	.014	.011	.028	.015	.020	.19	.23	.23	.40	.20	.24	.24	.035	.029	.031
9	AA	.003	.003	.007	.025	.004	.009	.007	.010	.006	.011	.015	.016	.014	.11	.13	.11	.40	.12	.14	.12	.025	.022	.025
10	AA	.003	.004	.006	.025	.008	.005	.006	.010	.009	.008	<.010	.021	.019	<.01	.03	.11	.40	.03	.04	.12	.015	.010	.027

* TTPI standards for total phosphorus, mg/ℓ.
**TTPI standards for total nitrogen, mg/ℓ.
***Total soluble inorganic nitrogen.
Underscored data represent violations of TTPI standards.

Kwajalein Atoll

Gugeegue and Ebeye were sampled in Kwajalein Atoll (Figure 6). Four sites from Gugeegue and five sites from Ebeye were sampled on November 27-29, 1979 (Figures 7 and 8). All lagoon samples (sites 1, 3, 5, 7, and 9) were taken by boat, whereas the ocean samples (sites 2, 4, 6, and 8) were obtained by wading out from shore. In order to check the quality of the lagoon water at the sewage outfall, a single sample was taken on November 29th (site 5b). The sampling sites were:

Gugeegue

1. LAGOON; 75 m offshore; sandy bottom with isolated patches of coral.

2. OCEAN; 30 m from shore between helicopter control tower and house; algae on rocks, slippery.

3. LAGOON; 50 m south of dock; 75 m offshore; sandy/coral rubble bottom.

4. OCEAN; 50 m from shore; algae on rocks, slippery; distinct current (SSW) toward cut between islands.

Ebeye

5. LAGOON; south of sewage outfall pipe; 75 m out from yellow house with concrete wall; children swimming near shore.

5b. LAGOON; at sewage outfall.

6. OCEAN; 30 m from shore at King Kabua-Kabua offical residence.

7. LAGOON; north of dock; 75 m from shore at power plant.

8. OCEAN; 50 m offshore at hospital.

9. LAGOON; 50 m from shore at old Coast Guard Station; south of 6 concrete poles protruding from the water.

Sampling time, tide, depth of site and current direction data are presented in Table 12. Differences in depth for site 1 were attributed to boat drift. Water quality data are presented in Tables 13 and 14. Total P concentrations were $\leq$0.014 mgP/ℓ for all samples. Violations of TTPI standards for total N of Gugeegue were attributed to analytical error in the TKN procedure; average values

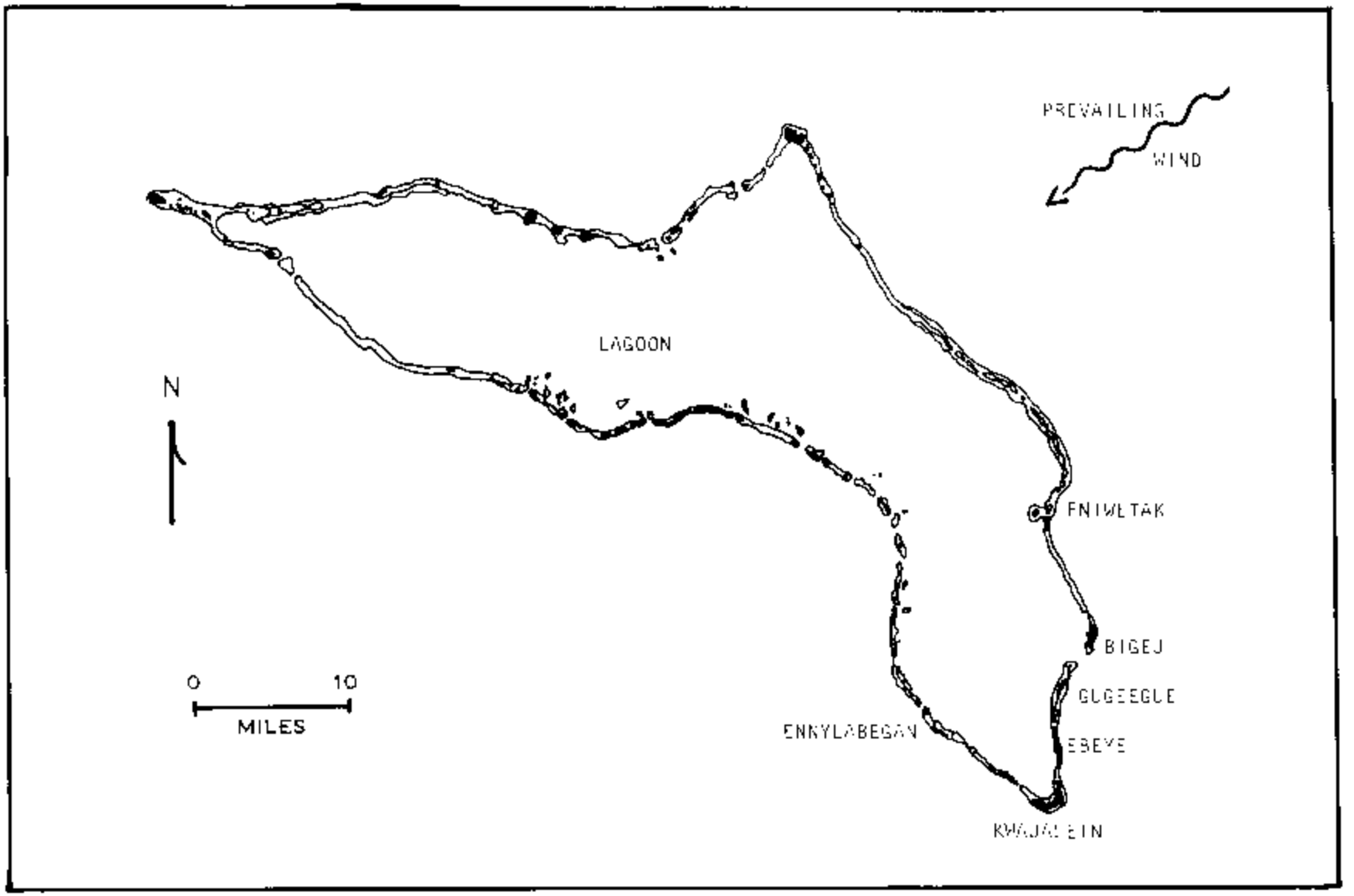

Figure 6. Kwajalein Atoll.

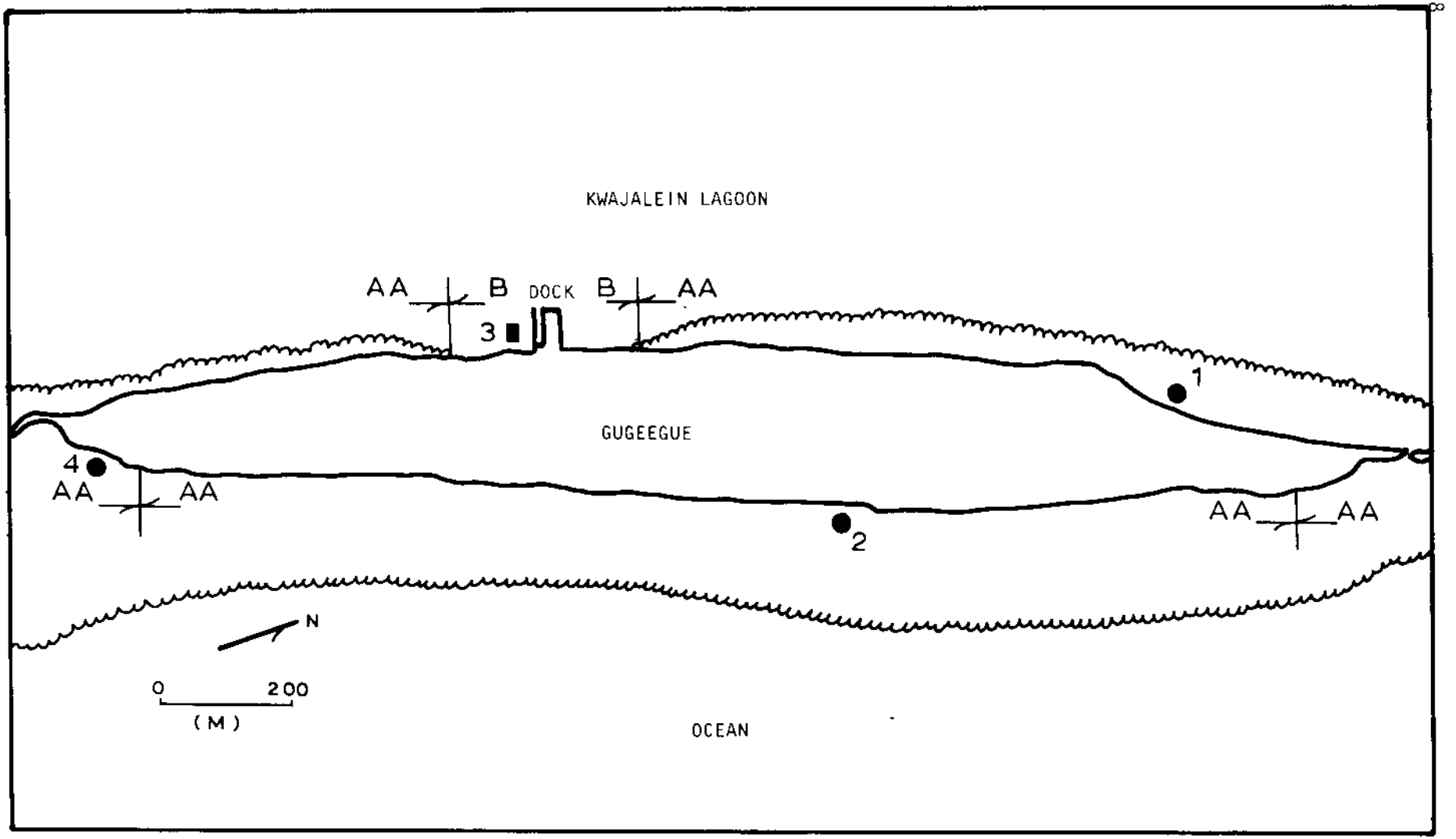

Figure 7. Sampling sites at Gugeegue Islet, Kwajalein Atoll. The circles are AA waters and the square is B water.

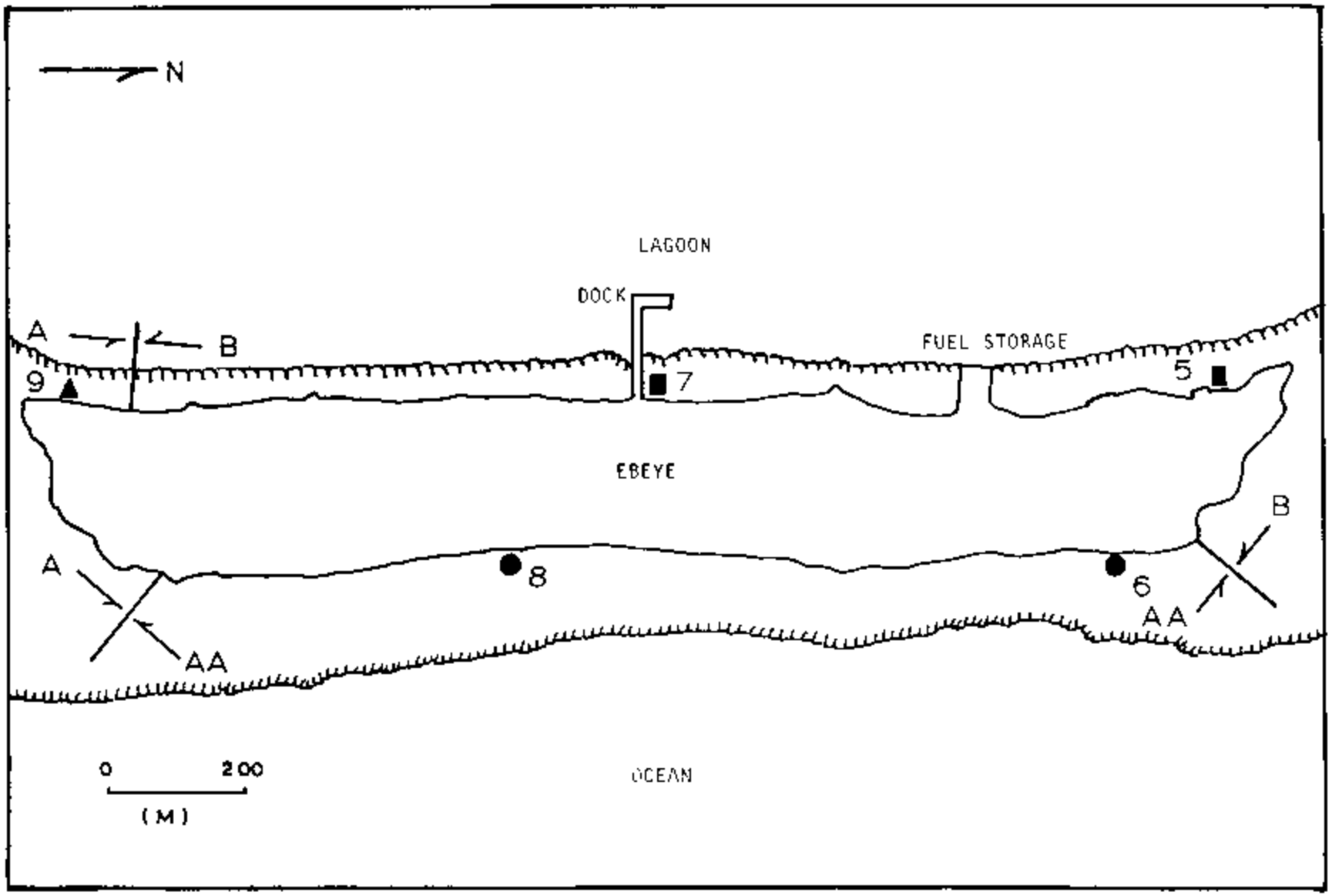

Figure 8. Sampling sites at Ebeye Islet, Kwajalein Atoll. The circles are AA waters, the triangle is A water and the squares are B waters.

Table 12. Physical characteristics at Ebeye/Gugeegue sampling sites.

	SITE	TTPI CLASS	SAMPLING TIME			TIDE			DEPTH OF SITE (m)			CURRENT DIRECTION (RELATIVE VELOCITY)		
EBEYE/	1	AA	1020	0945	0955	--	SR	SR	4.5	2.7	4.5	S	S	NNW
GUGEEGUE	2	AA	1105	1030	1045	--	SR	SR	0.7	0.5	0.3	SW	S	ENE
November 27-29	3	B	1040	1000	1025	--	SR	SR	3.5	3.0	3.2	ESE	SSE	WNW
1979	4	AA	1135	1050	1130	--	SR	SR	0.7	0.5	0.5	SW	SSW	SSW
	5	B	1205	1125	1210	--	SR	SR	1.5	1.5	1.5	SW	SE	W
	5b	B	--	--	1220	--	--	SR	--	--	8.0	--	--	WNW
	6	AA	1325	1220	1315	--	NEAP	SR	1	0.7	1	SE	ESE	NNW
	7	B	1215	1135	1230	--	SR	SR	2.2	1.5	2.2	W	S	SSW
	8	AA	1405	1245	1335	--	SF	NEAP	0.5	0.7	1	SSW	S	N
	9	A	1230	1145	1245	--	SR	SR	1.2	1.2	1.5	- (W)	NNE	W

TIDE:

SR - Strong rising
SF - Strong falling
NEAP - 30 min. before and after tide change.

CURRENT VELOCITY:

(W) Weak current

Table 13. Physical and bacteriological characteristics of water at Ebeye/Gugeegue sampling sites.

STATION	TIPI CLASS	WATER TEMPERATURE °C			TURBIDITY NTU			pH			DISSOLVED OXYGEN mg/l			SALINITY o/oo			TOTAL COLIFORMS #/100 ml			FECAL COLIFORMS #/100 ml		
1	AA	29.2	28.9	29.1	0.2	0.4	0.1	8.15	8.10	8.18	6.65	6.98	6.10	34	33	34	8	0	0	0	0	0
2	AA	29.0	29.2	29.5	0.4	0.2	0.2	8.18	8.32	8.40	7.50	6.79	6.99	34	34	34	0	0	0	0	0	0
3	B	29.2	28.5	29.0	0.4	1.4	0.3	8.22	8.20	8.20	5.96	6.42	6.67	34	34	34	342	20	0	134	0	0
4	AA	29.6	29.3	29.2	0.2	0.2	0.8	8.38	8.35	--	6.76	6.96	6.98	34	34	34	2	0	1	0	0	0
5	B	29.8	29.1	29.1	0.3	0.2	0.5	8.15	8.30	8.20	8.32	7.08	7.43	34	34	34	10	8	22	<10	2	6
5b	B	--	--	29.2	--	-	0.2	--	--	8.20	--	--	6.73	-	--	34	--	--	0		-	0
6	AA	29.1	29.3	29.0	0.1	0.1	0.1	8.30	8.30	8.22	6.20	6.93	6.60	34	34	34	<10	93	30	10	2	0
7	B	29.5	29.2	29.4	0.8	0.7	0.2	8.28	8.32	8.20	7.98	8.32	6.73	34	34	34	10	6	150	<10	6	2
8	AA	29.5	29.3	29.2	0.4	0.2	0.2	8.20	8.37	8.25	6.91	6.71	6.65	34	34	34	30	22	62	10	1	15
9	A	29.8	29.3	29.5	0.4	0.8	0.4	8.40	8.30	8.30	9.82	8.20	9.62	34	34	34	<10	240	460	10	18	0

Table 14. Chemical characteristics of water at Ebeye/Gugeegue sampling sites.

STATION	TTPI CLASS	PO_4-P mg/ℓ			TOTAL P mg/ℓ *				$(NO_3 + NO_2)$-N mg/ℓ			NH_3-N mg/ℓ			TKN mg/ℓ			TOTAL N mg/ℓ **				TSIN*** mg/ℓ		
1	AA	.007	.008	.009	.025	.007	.009	.009	.013	.005	.005	.013	< .010	< .010	.16	.72	.36	.40	.17	.73	.37	.026	.010	.010
2	AA	.006	.006	.009	.025	.006	.011	.012	.010	.008	.004	.011	.011	.012	.08	1.17	.30	.40	.08	1.18	.30	.021	.019	.016
3	B	.009	.003	.009	.100	.009	.009	.009	.016	.010	.005	.016	.016	.015	.14	.03	1.88	1.50	.16	.04	1.89	.032	.026	.020
4	AA	.006	.007	.008	.025	.006	.008	.008	.008	.003	--	.012	< .010	< .010	.25	.03	.30	.40	.26	.03	.46	.020	.008	--
5	B	.007	.008	.007	.100	.011	.010	.014	.010	.009	.017	.012	< .010	.018	.19	.01	.15	1.50	.20	.02	.17	.022	.014	.035
5b	B	--	--	.005	.100	--	--	.009	--	--	.007	--	--	< .010	--	--	.36	1.50	--	--	.37	--	--	.012
6	AA	.010	.006	.006	.025	.010	.007	.006	.011	.003	.007	.043	.013	.019	.29	.19	.38	.40	.30	.19	.39	.054	.016	.026
7	B	.006	.005	.009	.100	.008	.011	.009	.006	.010	.003	.013	.020	.011	.03	.13	.50	1.50	.04	.14	.50	.019	.030	.014
8	AA	.009	.008	.008	.025	.009	.008	.008	.010	.013	.006	.014	.016	.011	.27	.05	.12	.40	.28	.06	.13	.024	.029	.017
9	A	.004	.006	.007	.050	.009	.014	.008	.010	.007	.009	.022	< .010	< .010	.35	.35	.21	.75	.36	.36	.22	.032	.012	.014

* TTPI standards for total phosphorus, mg/ℓ.
**TTPI standards for total nitrogen, mg/ℓ.
***Total soluble inorganic nitrogen.
Underscored data represent violations of TTPI standards.

for total N concentrations omitting questionable data were 0.27, 0.19 and 0.25 mgN/ℓ for sites 1, 2 and 4 (class AA), 0.10 mgN/ℓ for site 3 (class B).

Bacteriological data gathered in this study indicate decreases in total and fecal coliform concentrations in Ebeye class B waters when comparisons are made using similar sample sites from previous studies (Table 1). It is noted that such improvements are only estimates because of lack of an adequate number of samples to accurately describe conditions. Data in Table 15 represent single samples for the Amesbury et al. (1975) and M & E Pacific and J. C. Tenorio (1978) studies; data from the current study represent the mean values of three samples at each site.

Palau

Thirteen sites surrounding Koror Island were sampled on December 19-21, 1979 (Figure 9). All samples were collected by boat. Delays in transportation of laboratory and field equipment (Continental Air Micronesia) caused scheduling problems in the sampling program. Sites 1, 2, 3, 4, 6, 10, 11, 12 and 13 were shallow stations with sparse seagrass/sandy bottoms. The sampling sites were:

1. IWAYAMA BAY; southeast of weather station; 50 m from shore.

2. IWAYAMA BAY; in the center of a small bay surrounded by rock islands.

3. IWAYAMA BAY; southeast from Continental Hotel Dock; 30 m east of a small island.

4. IWAYAMA BAY; south of Continental Hotel; 30 m west of rock island.

5. PORT OF PALAU, MALAKAL ISLAND; 30 m off east side of Van Camp.

6. MEYUNS; 50 m from shore, lined with mangroves (houses located behind mangroves).

7. NGAROL ISLAND; in channel 25 m from island.

8. NGARDIS; 50 m from shore.

9. OLD AIRPORT; 50 m from stone wall.

10. KOMEBAIL LAGOON; 30 m east from shore.

11. SECHEMUS; 50 m from shore, lined with mangroves (houses located behind mangroves).

Table 15. Total and fecal coliform concentrations (#/100mℓ) for Ebeye class B waters.

REFERENCE	DATE	SEWER OUTFALL		DOCK	
		T.C.	F.C.	T.C.	F.C.
Amesbury et al. (1975)	Aug. 1975	---	278	---	1720
M&E Pacific and J.C. Tenorio (1978)	Aug. 1978	400	50	TNTC*	600
Cowan, Clayshulte (1980)	Nov. 1979	15	6	55	5

*TNTC = too numerous to count.

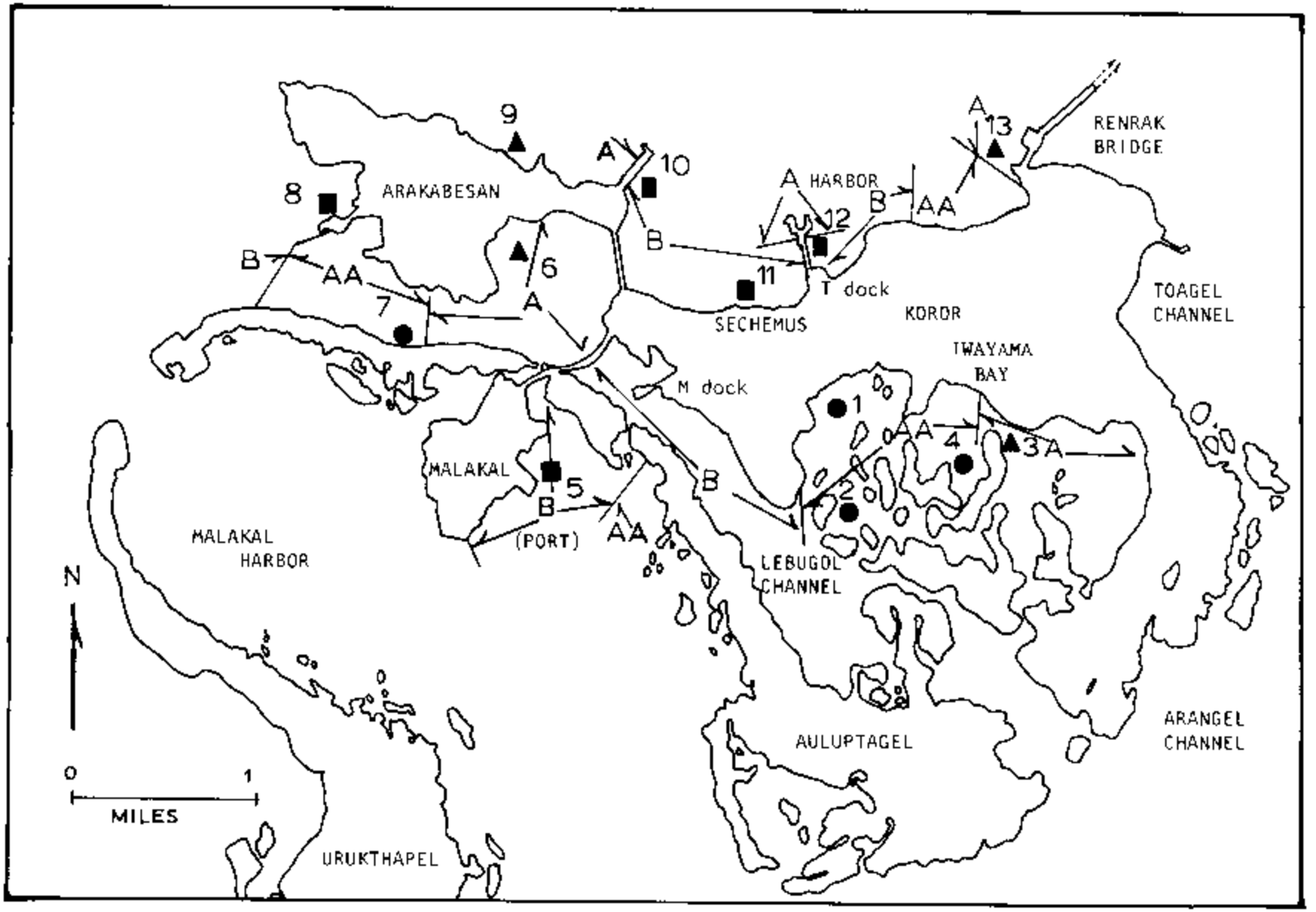

Figure 9. Sampling sites at Koror, Palau. The circles are AA waters, the triangles are A waters and the squares are B waters.

12. T-DOCK area; southeast from fish market; 30 m from shore.

13. RENRAK BRIDGE area; 100 m west from shore.

Sampling time, tide, depth of site, Secchi depth and water current data are listed in Table 16. Late arrival of sampling equipment necessitated the December 19 samples being gathered in the late afternoon. The remaining two sample periods were taken in the morning. Differences in station depths for site 7 were due to boat drift. The waters of the deep stations (sites 5 and 7) were observed to have a green color. Secchi depth mean values were 8 m and 12 m respectively. Average dissolved oxygen concentrations for TTPI class AA sites 1, 2, 4 and 7 were 6.23, 5.75, 6.10 and 6.17 mg/ℓ respectively. It was concluded that only site 2 was in violation of the class AA TTPI D.O. level (<6.0 mg/ℓ). Site 2 was located in Iwayama Bay in shallow water of high clarity (turbidity average: 0.4 NTU) and low total and fecal coliform concentrations ($\leq$ 1/100 mℓ); therefore, it is anticipated that minimum importance should be placed upon the violation of DO standards.

Physical, chemical and bacteriological data are presented in Tables 17 and 18. Total and fecal coliform concentrations for the December 19th samples were determined utilizing 1 mℓ aliquots for all sites. Only site 8 showed any colonies (4 total coliform/mℓ). The low sample volumes were used because of suspected high coliform concentrations (R. Barker, personal communication). Consequently, all microbiological data for this sampling period were omitted from subsequent analyses. Calculations for mean coliform concentrations for the waters surrounding Koror will include only data from the December 20-21, 1979 data sets.

Total P concentrations were $\leq$ 0.013 mgP/ℓ for all waters except site 1 (December 19, 0.023 mgP/ℓ) and those off the Van Camp cannery (site 5, December 19, 0.079 mgP/ℓ). Although site 5 was not in violation of the class B water quality standard for total P (0.100 mgP/ℓ), this area warrants concern because the orthophosphate phosphorus (PO_4-P) concentration on December 19 was 0.036 mg PO_4-P/ℓ. Total N concentration for site 5 was highest on December 19 (0.42 mgN/ℓ); however, the mean Total N value for the study was only 0.21 mgN/ℓ. A total N concentration in excess of the class AA standards (0.40 mgN/) was observed on December 20 at site 1 (0.54 mgN/ℓ). Since the average total N concentration for this site was 0.36 mgN/ℓ, site 1 was not in violation of the TTPI standard.

Yap

Thirteen sites were sampled around the central islands of Yap on December 24, 26 and 27, 1979 (Figure 10). All samples were obtained by boat. It was impossible to sample all stations prior to low tide; therefore, site 4 was omitted. Site descriptions (1-11)

Table 16. Physical characteristics at Koror sampling sites.

	SITE	TTPI CLASS	SAMPLING TIME	TIDE	DEPTH OF SITE (m)	SECCHI (m)	CURRENT DIRECTION (RELATIVE VELOCITY)
	1	AA	1620 0905 0843	SR WF NEAP	0.6 1.2 1.2		NW (W) SSW(W)
PALAU	2	AA	1633 0850 0830	SR WF NEAP	1.2 1.5 1.7		NW (M) SE (W)
KORDR	3	A	1600 0928 0852	SR WF NEAP	1 1.2 1.5		WSW(M) - (W) --
December 19-21	4	AA	1610 0918 0846	SR WF NEAP	1 1.7 1.7		W (W) -- (W) --
1979	5	B	1650 1113 1013	SR WF WF	24 24 24	7 8.5 9	-- (W) SE (W)
	6	A	1712 1052 0958	SR WF WF	1 0.5 1		-- (W) -- (W) --
	7	AA	1702 1102 1005	SR WF WF	11 11 14	11 11 14	E (-) W (W) --
	8	B	1724 1036 0947	SR WF WF	3.7 3.5 3.2		-- (W) -- (W)
	9	A	1735 1025 0939	SR WF WF	1.2 1 1.2		WNW(W) NW (M) --
	10	B	1745 1014 0905	SR WF NEAP	1.2 1 1.2		SSW(W) NNE(W) --
	11	B	1755 0945 0915	SR WF WF	1 1 1.2		WSW(W) WNW(W) --
	12	B	1803 0954 0920	SR WF WF	1.2 1 1.5		W (W) WNW(W)
	13	A	1815 1005 0926	SR WF WF	-- 1.1 1.2		-- N (W) --

TIDE:
SR - Strong rising
WF - Weak falling
NEAP - 30 min. before and after tide change

CURRENT VELOCITY:
(W) weak
(M) moderate

Table 17. Physical and bacteriological characteristics of water at Koror sampling sites.

STATION	TTPI CLASS	WATER TEMPERATURE °C			TURBIDITY NTU			pH			DISSOLVED OXYGEN mg/ℓ			SALINITY o/oo			TOTAL COLIFORM #/100 mℓ			FECAL COLIFORM #/100 mℓ		
1	AA	31.5	29.5	30.0	2.4	0.7	0.9	7.80	7.79	7.79	8.11	5.07	5.50	31	32	33	<100	4	1	<100	0	0
2	AA	29.9	29.5	29.5	0.5	0.5	0.4	7.90	8.00	7.95	5.81	5.42	6.02	32	32	33	<100	0	0	<100	1	0
3	A	30.3	30.0	29.5	0.4	0.7	0.5	7.98	8.00	7.90	6.70	5.50	5.93	32	32	32	<100	0	7	<100	0	0
4	AA	30.6	29.5	29.5	0.8	0.4	0.5	8.00	7.99	7.90	7.56	5.50	5.24	32	32	33	<100	1	1	<100	0	0
5	B	29.2	29.5	29.0	0.8	0.6	0.4	8.00	8.12	8.05	5.85	5.81	6.02	32	33	34	<100	0	5	<100	0	1
6	A	31.2	30.0	29.5	1.6	1.5	1.1	8.00	7.89	8.00	8.30	5.42	5.67	32	34	34	<100	0	15	<100	0	4
7	AA	28.9	29.0	29.0	0.4	0.4	0.5	7.98	8.11	8.10	6.36	5.97	6.19	32	33	34	<100	0	0	<100	0	0
8	B	29.7	29.0	29.5	0.4	0.3	0.5	8.00	8.11	8.10	7.70	5.67	5.67	32	33	34	400	6	0	<100	1	0
9	A	29.1	29.0	29.0	0.6	0.4	0.6	7.90	7.98	8.10	6.88	6.15	6.02	32	33	34	<100	4	0	<100	0	1
10	B	29.2	29.0	29.5	1.2	0.8	0.7	7.92	7.91	8.10	7.89	5.67	5.67	32	33	34	<100	51	8	<100	2	0
11	B	29.7	29.0	29.5	1.1	1.1	0.8	7.98	7.81	8.05	7.91	4.85	5.07	32	33	33	<100	20	17	<100	0	1
12	B	29.3	29.0	29.8	0.8	0.8	0.6	7.98	8.01	8.15	6.19	6.02	6.10	32	33	33	<100	10	22	<100	0	36
13	A	--	29.5	29.2	0.6	0.7	0.6	7.75	8.04	8.15	6.72	6.33	6.28	32	33	33	<100	2	1	<100	0	3

Underscored data represents violations of TTPI standards.

Table 18. Chemical characterisites of water at Koror sampling sites.

STATION	TTPI CLASS	PO_4-P mg/l			TOTAL P mg/l *				$(NO_3 + NO_2)$-N mg/l			NH_3 N mg/l			TKN mg/l			TOTAL N mg/l **				T-C mg/l		
1	AA	.001	<.010	.009	.025	.029	.030	--	.038	.016	.014	.041	.033	.014	.25	.52	.25	.40	.29	.56	.26	.029	.069	.038
2	AA	.004	<.008	.003	.025	.004	.008	--	.016	.023	.015	.027	.017	.012	.38	.18	.16	.60	.60	.20	.38	.054	.040	.027
3	A	.004	<.013	-	.050	.004	.013	--	.012	.005	.006	.042	.015	--	.25	.12	.35	.75	.26	.12	.31	.054	.020	-
4	AA	-	<.008	.004	.025	.007	.008	--	.017	.011	.013	--	.026	.020	.34	.18	.18	.40	.36	.19	.39	--	.037	.014
5	B	.036	<.011	.006	.100	.079	.011	--	.018	.023	.013	.036	.014	.067	.40	.06	.11	1.50	.42	.08	.14	.054	.037	.080
6	A	--	.006	--	.050	.005	.010	.012	.016	.001	.009	--	--	--	.29	<.01	.16	.75	.31	<.01	.17	-	.006	--
7	AA	.011	<.008	.001	.025	.011	.008	.007	.016	.020	.011	.018	.028	.018	.27	.38	<.01	.40	.29	.40	.07	.036	.048	.029
8	B	.001	<.010	.007	.100	.008	.010	.008	.018	.014	.016	.012	.017	.018	.36	.13	.07	1.50	.38	.14	.09	.030	.031	.014
9	A	.004	<.006	.005	.050	.008	.006	.009	.014	.001	.011	.021	.018	.017	.15	.08	.08	.75	.16	.08	.09	.035	.019	.020
10	B	.009	--	.002	.100	.009	.008	.008	.018	.019	.010	.015	-	.025	.12	.12	.13	1.50	.34	.14	.14	.043	-	.019
11	B	.007	<.011	<.009	.100	.008	.013	.009	.015	.010	.013	.015	.016	.018	.22	.43	.37	1.50	.24	.44	.38	.030	.026	.011
12	B	.008	<.010	.001	.100	.013	.010	.006	.017	.011	.017	.035	.020	--	.11	.25	.15	1.50	.13	.26	.16	.052	.041	--
13	A	.010	<.008	.002	.050	.010	.008	.008	.018	.002	.009	.020	.045	.018	.30	.08	.26	.75	.12	.08	.27	.038	.047	.027

* TTPI standards for total phosphorus, mg/l.
**TTPI standards for total nitrogen, mg/l.
***Total soluble inorganic nitrogen.
Underscored data represent violations of TTPI standards

Table 19. Physical characteristics at Yap sampling sites.

	SITE	TTPI CLASS	SAMPLING TIME			TIDE			DEPTH OF SITE (m)			SECCHI (m)		
YAP	1	B	1415	1525	1445	WF	WF	NEAP	1	1.2	1.5			
December	2	B	1405	1515	1450	WF	WF	NEAP	1	1	1.5			
24,26,27	3	AA	1345	1455	1500	WF	WF	WF	1	1	1			
1979	5	AA	--	1355	1330	--	WF	WR	--	1	1			
	6	A	1305	1330	1310	WF	NEAP	WR	1.5	1	1			
	7	AA	--	1245	1245	--	WR	WR	--	1.2	2.7			
	8	A	1220	1225	1223	WF	WR	WR	1.7	1.7	2			
	9	AA	1206	1214	1211	WF	WR	WR	2.2	1.7	1.2			
	10	A	1145	1155	1155	NEAP	WR	WR	8	9.5	4	8	--	--
	11	AA	1125	1137	1135	NEAP	WR	WR	2.2	1.7	1.5			
	12	AA	1437	1440	1435	WF	WF	NEAP	1	1	1.7			
	13	B	1500	1426	1430	WF	WF	NEAP	1	1.5	3			
	14	B	1514	1530	1530	WF	WF	WF	1.5	1.7	1.7	0.5	1.7	1.2

TIDE:
WF - Weak falling
WR - Weak rising
NEAP ~ 30 min. before and after tide change

(3, 11 and 12). Average D.O. concentrations for these three sites were 8.58, 6.11 and 6.18 mg/ℓ respectively. It was concluded that sites 3, 11 and 12 were not in violation of TTPI standard.

Physical, chemical and bacteriological data are listed in Tables 20 and 21. Consistently lower water temperatures and salinities and correspondingly higher turbidities and coliform concentrations (Table 20) existed on December 24. These phenomena were attributed to the rainfall on December 23 and 24 (Table 8). The rains washed silt, sediment and bacteria from the islands into the surrounding marine waters. High total coliform concentrations (listed in Table 20 as TNTC) were not anticipated for sites 1, 2, 8, 9 and 12; therefore, only 50 and 100 mℓ aliquots were analyzed on December 24. Since ideal quantities of coliform bacteria result in growth of about "20 to 80 coliform colonies and less than 200 total bacterial colonies" (A.P.H.A., 1975; p. 934), the total coliform concentrations at these sites were estimated to be >100/100 mℓ. Site 14 was assayed at 1, 10 and 100 mℓ aliquots for total coliform (listed in Table 20 as TNTC). Total coliform concentration of the Chamorro Bay site was estimated to be >10,000/100 mℓ (December 24).

High fecal coliform concentrations (listed in Table 20 as TNTC) were not anticipated for site 1; only a 100 mℓ aliquot was analyzed on December 24. Ideal fecal coliform concentrations result in a growth of between "20 to 60 fecal" colonies (A.P.H.A., 1975; p. 939); therefore, fecal coliform concentration on this date for site 1 was estimated to be 60/100 mℓ. Violations of class A and class B fecal coliform standards were quantified on December 24 (site 6; class A), December 26 (site 1; class B). The Chamorro Bay site (14; class B) was in violation of the standard (fecal coliform >400/100 mℓ) on all sampling dates.

Dissolved oxygen (D.O.) concentration for bottom waters at site 14 was quantified on December 26 as 5.34 mg/ℓ. It was concluded from this single observation that anaerobic conditions did not exist in the bottom waters of Chamorro Bay. Lack of anaerobic conditions in these bottom waters was attributed to phytoplankton growth and mixing regimes. Light penetration, indicated by Secchi depth measurement of 1.7 m (bottom, December 26) was sufficient to promote phytoplankton growth in the bottom waters. The mixing of Chamorro Bay waters was sufficient to prevent D.O. stratification.

A violation of the TTPI class AA total P standard was observed at site 11 (December 27). The mean total P concentration for site 11 for the three days studied was 0.016 mgP/ℓ, which is less than the TTPI standard for AA waters (0.025 mgP/ℓ). It is noted that there were no total N violations and that the PO_4-P levels for all sites were ≤0.006 mg PO_4-P/ℓ (with all but 4 sites [8, 10, 11 and 14: December 24] being ≤0.003 mg PO_4-P/ℓ).

Table 20. Physical and bacteriological characteristics of water at Yap sampling sites.

STATION	TTPI CLASS	WATER TEMPERATURE °C			TURBIDITY NTU			pH			DISSOLVED OXYGEN mg/ℓ			SALINITY o/oo			TOTAL COLIFORM #/100 mℓ			FECAL COLIFORM #/100 mℓ		
1	B	27.5	30.5	30.0	2.8	1.4	0.9	8.00	8.10	8.18	5.93	7.91	8.72	26	30	30	TNTC	430	260	TNTC	670	300
2	B	27.0	30.5	30.0	2.2	2.0	1.2	8.00	8.02	8.20	5.76	8.11	9.68	27	27	30	TNTC	140	60	196	120	90
3	AA	27.0	29.0	31.0	0.8	0.3	0.5	7.98	8.30	8.30	5.67	10.28	9.80	27	33	33	87	6	7	38	0	2
5	AA	--	29.5	30.0	--	0.5	0.4	--	8.30	8.22	--	8.94	9.80	--	33	34	--	68	2	--	8	0
6	A	27.5	28.0	30.0	0.3	0.7	0.3	8.00	8.12	8.25	6.02	8.11	8.48	31	33	34	3200	60	3	810	0	1
7	AA	--	28.0	30.0	--	0.8	0.4	--	8.20	8.15	--	7.91	7.00	--	34	34	--	2	3	--	0	0
8	A	27.8	27.5	29.0	0.5	0.5	0.3	8.05	8.11	8.18	6.15	7.22	7.53	31	34	33	TNTC	50	6	58	0	0
9	AA	26.5	27.5	29.0	1.8	0.8	0.5	8.02	8.10	8.11	6.57	6.96	6.70	26	31	33	TNTC	80	2	116	2	0
10	A	27.5	27.5	29.5	1.2	1.5	0.5	8.01	8.11	8.10	5.36	7.13	6.74	31	34	34	93	20	0	161	20	0
11	AA	27.0	27.0	30.0	0.5	0.6	2.1	8.00	8.10	8.08	5.16	6.88	6.28	31	31	30	50	16	9	82	4	1
12	AA	27.0	28.5	30.0	2.8	1.3	1.2	7.87	8.08	8.10	5.55	6.53	6.45	25	32	32	TNTC	50	7	397	0	2
13	B	28.5	28.5	30.0	1.1	0.9	0.9	7.98	8.11	8.11	5.67	7.91	8.08	29	30	32	85	6	2	53	4	14
14	B	27.0	30.5	31.0	13.0	4.1	4.7	7.80	8.02	8.05	6.15	6.50	6.70	17	27	26	TNTC	1600	1400	12,700	7600	2000

Underscored data represent violations of TTPI standards.
TNTC = to numerous to count.

Table 21. Chemical characteristics of water at Yap sampling sites.

Station	TTPI Class	PO_4-P mg/ℓ			Total P mg/ℓ *				$(NO_3 + NO_2)$-N mg/ℓ			NH_3-N mg/ℓ			TKN mg/ℓ			Total N mg/ℓ **				TSIN *** mg/ℓ		
1	B	.001	<.001	<.001	.100	.011	.010	.009	.018	.006	.006	.013	.015	.027	.13	.18	.43	1.50	.15	.19	.44	.051	.021	.033
2	B	.001	<.001	<.001	.100	.010	.012	.010	.014	.006	.011	.027	.042	.019	.29	.04	.06	1.50	.30	.05	.07	.041	.048	.030
3	AA	.001	<.001	<.001	.025	.009	.008	.008	.011	.009	.005	.022	.012	.027	.17	.06	.14	.40	.18	.07	.15	.033	.021	.032
5	AA	--	<.001	.002	.025	--	.008	.009	--	.007	.006	--	.014	.015	--	.18	.08	.40	--	.19	.09	--	.021	.021
6	A	.003	.001	.001	.050	.011	.008	.013	.016	.010	.008	.064	.012	.017	.17	.13	.16	.75	.19	.14	.17	.080	.022	.025
7	AA	--	<.001	.003	.025	--	.010	.009	--	.013	.008	--	--	.026	--	.05	.06	.40	--	.06	.07	--	--	.034
8	A	.006	<.001	.011	.050	.008	.009	.008	.013	.008	.007	.047	.014	.023	.33	.13	.25	.75	.34	.14	.26	.056	.022	.030
9	AA	<.001	<.001	<.001	.025	.011	.006	.008	.011	.009	.004	.023	.028	.027	.11	.05	.18	.40	.12	.06	.16	.034	.037	.031
10	A	.006	<.001	.002	.050	.005	.010	.008	.010	.010	.011	.022	.026	.019	--	.12	.16	.75	--	.13	.17	.032	.034	.030
11	AA	.006	<.001	.001	.025	.010	.009	.030	.011	.010	.011	.042	.013	.027	.18	.11	.13	.40	.19	.12	.14	.053	.021	.028
12	AA	.001	<.001	.001	.025	.009	.010	.008	.015	.013	.010	.028	.026	.033	.18	.18	.21	.40	.20	.19	.22	.043	.039	.043
13	B	.002	<.001	.001	.100	.012	.012	.008	.015	.009	.008	.029	.018	.016	.09	.07	.09	1.50	.11	.08	.10	.034	.027	.024
14	B	.006	<.001	.002	.100	.026	.016	.019	.040	.011	.012	.070	.072	--	.19	.15	.08	1.50	.23	.16	.09	.110	.063	--

* TTPI standards for total phosphorus, mg/ℓ.
** TTPI standards for total nitrogen, mg/ℓ.
*** Total soluble inorganic nitrogen.
Underscored data represent violations of TTPI standards.

Truk

Ten sites were sampled in the Truk lagoon on January 2-4, 1980 (Figure 11). Seven sites from the marine waters around Moen (Figure 12) and three from the waters around Dublon (Figure 13) were sampled. All sampling was done by boat. The sample locations were:

1. MOEN, CONTINENTAL HOTEL; west side of point, 45 m from small rocky shoreline with large sand spit 50 m east; site over small coral/sand patch reef, bottom sediments were a fine anaerobic sandy-mud; low to heavy surface debris with a large eddy current in area; area used for recreation.

2. DUBLON, NUKAM; 50 m south of high school, near a barge on the edge of a steep deep dropoff; water was generally clean in area with low surface debris.

3. DUBLON, ETEN (STONE PIER); 35 m west of pier and 70 m from shore; shallow *Porites* coral and cobble pavement, mangrove development along shoreline; trade winds pile water into area; water clean with low surface debris.

4. DUBLON, PENIOR; west side of bay 50 m from mangrove shoreline; reefflat with large *Porites* coral heads and sand patches with heavy seagrass growth; benjo and houses along shore; water in area pale yellow-green, low surface debris.

5. MOEN, EPINUP; shoreward end of large reefflat (400-500 m across) 30 m from mangroves and 20 m from channel (heavily lined with coral); bottom is sand with *Halimeda* clumps and seagrasses; numerous small fish in area, throw net fishing is done in area.

6. MOEN, WINIPIS (XAVIER); 45 m from stone breakwater below Xavier High School; mangrove clumps near shore; reefflat with extensive coral growth; water clean.

7. MOEN, SAPUK (STONE PIER); 10 m off end of stone pier inside reef margin, tied to west side of pier; heavy seagrass and surface debris; water murky during sampling with yellow-green tint; frequently used for recreation.

8. MOEN, PENIESENE (BAY); 40 m from shore in inner portion of bay between church and pink house; the bay is shallow, highly turbid with anaerobic sediments; fresh water input from small river; numerous benjos in area; heavy surface debris with water basically a muddy brown; area used for recreation and outer portions of bay are fished.

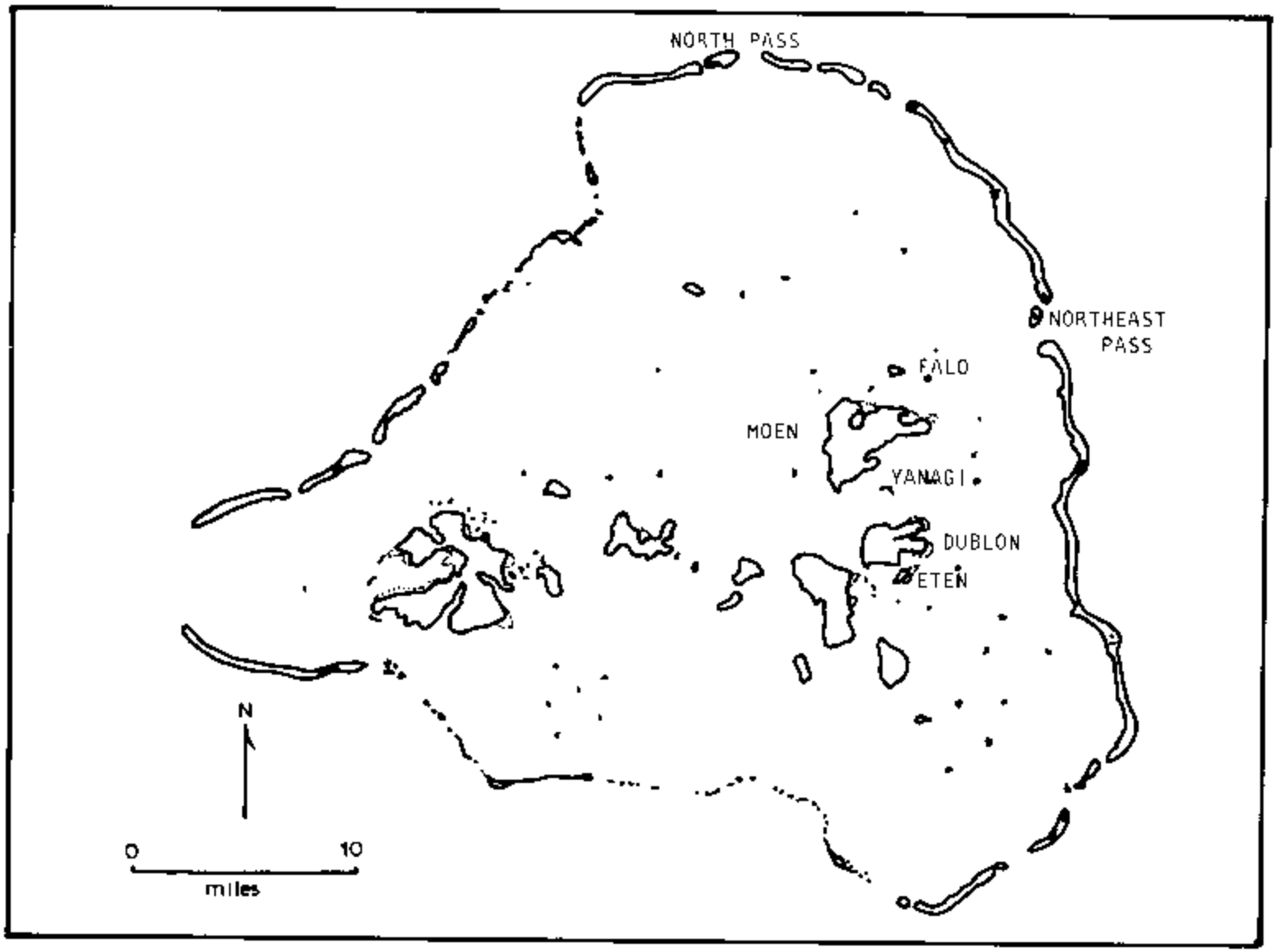

Figure 11. Truk Atoll.

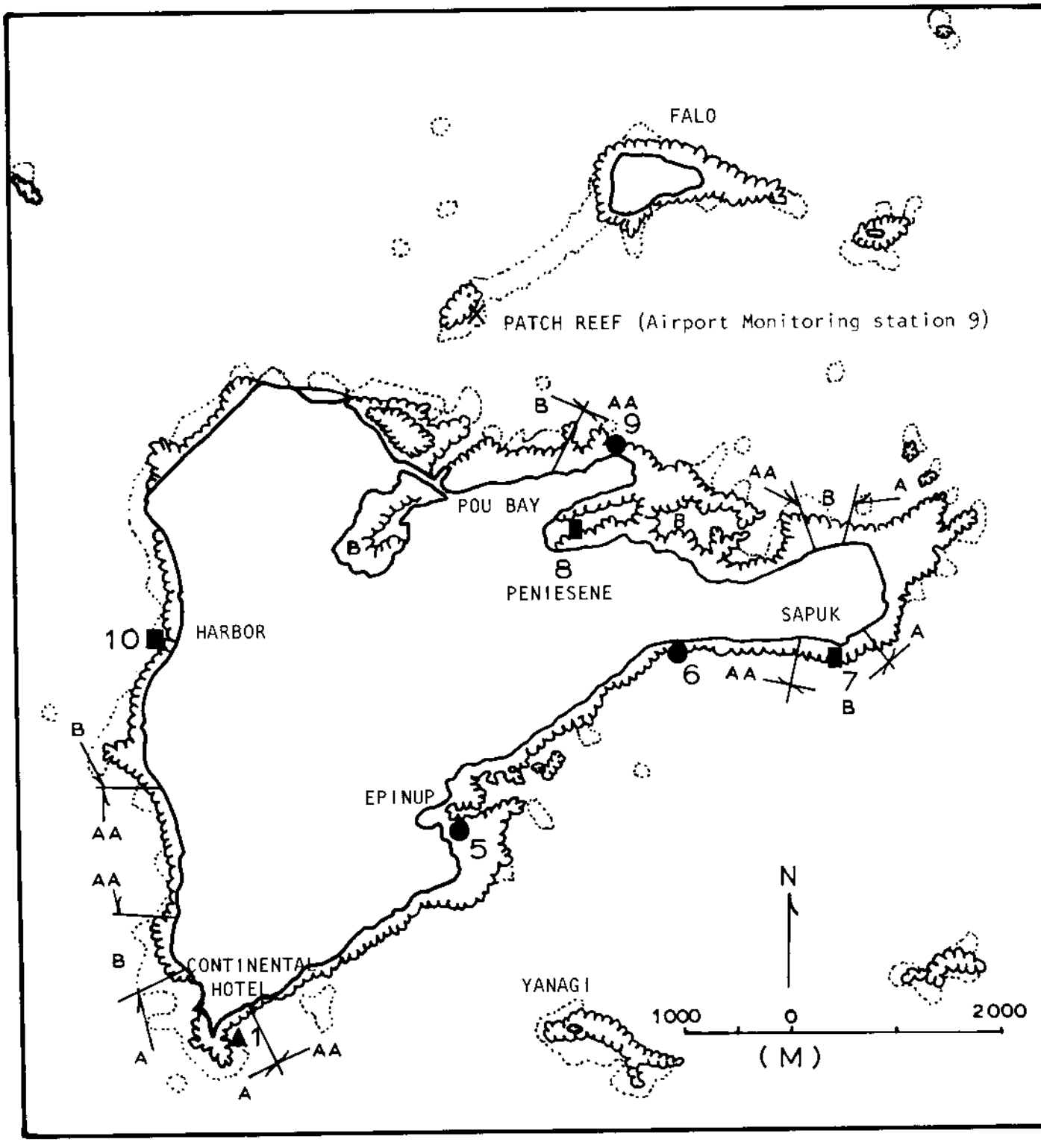

Figure 12. Sampling sites at Moen Island, Truk. The circles are AA waters, the triangle is A water and the squares are B waters.

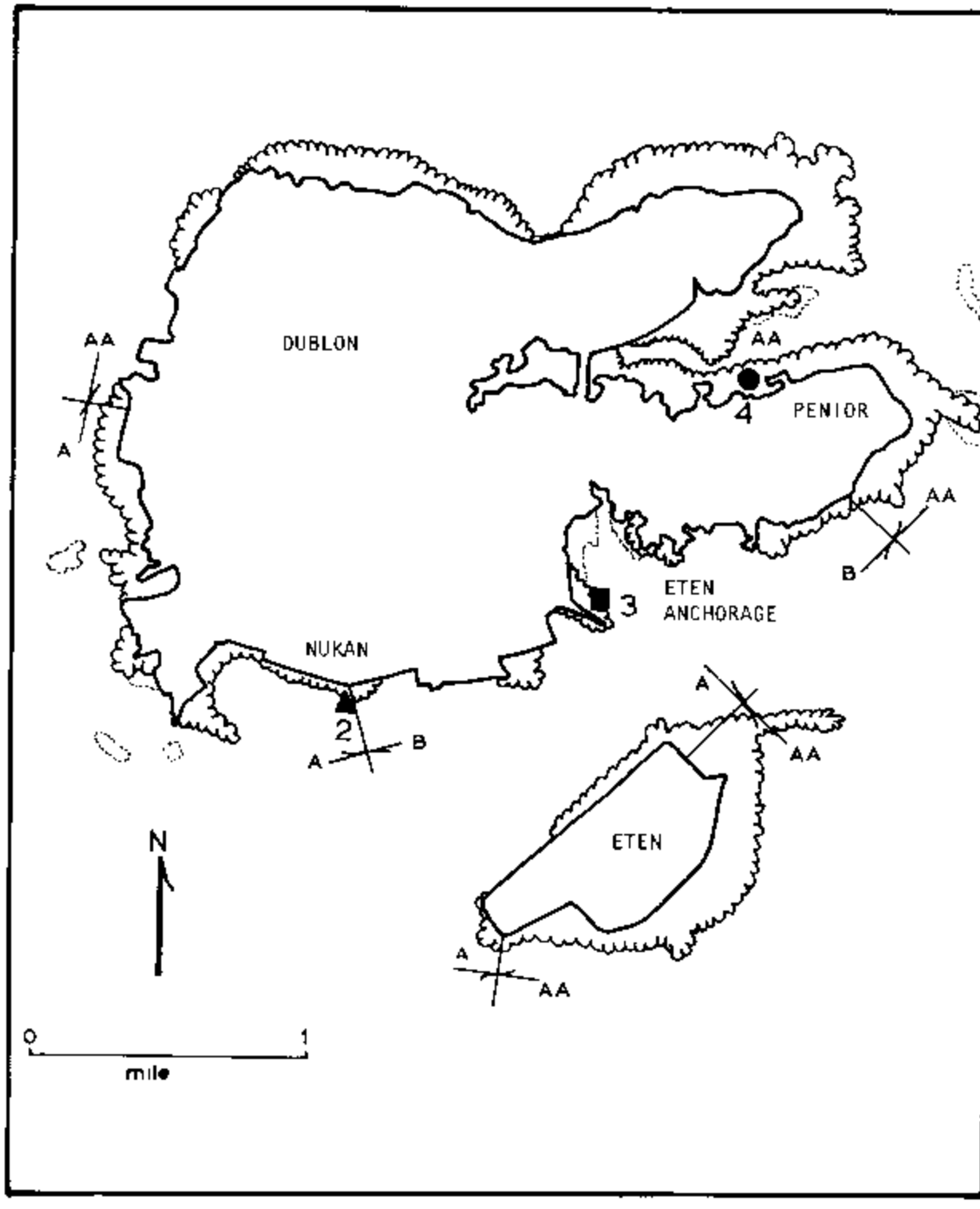

Figure 13. Sampling sites at Dublon Island, Truk. The circle is AA water, the triangle is A water and the square is B water.

9. MOEN, PENIESENE (POINT); west side of point 45 m from shore; extensive coral growth with large population of soft corals; no surface debris, pristine area.

10. MOEN HARBOR; west side near entrance, along dropoff with few scattered corals; oil slicks during sampling and 4-5 ships pumping bilges; heavy small boat traffic.

Sampling time, tide, depth of site, Secchi depth, water current and wind direction data are listed in Table 22. All stations were shallow except sites 1, 2, 7 and 10; differences in site depths at these stations were due to boat drift. Secchi depth measurements were taken at sites 2 (Dublon) and 8 (Moen). The site 2 waters were clear and Secchi disc measurements were attained solely due to the depth of the station. Site 8, however, was extremely turbid (brown, silt-laden waters); average site depth was 0.9 m with an average Secchi depth of 0.7 m.

Physical, chemical and bacteriological data are presented in Tables 23 and 24. High turbidity values were quantified (average turbidity: 6.7 NTU) for site 8. Violations of TTPI (class B) fecal coliform concentrations were measured on January 2 and 3 at site 8. Since this area is utilized for recreation, it is noted that a definite health hazard exists in the inner portion of this bay.

The irregularities in the (NO_3+NO_2)-N data for all sites except site 7 may be attributed to analytical error. The data for sites 1-6 and 10 (January 4) and for sites 8-10 (January 3) were omitted from subsequent calculations; therefore, (NO_3+NO_2)-N, total N and TSIN mean concentrations were determined as arithmetic averages of two samples for all sites (except sites 7 and 10). Total N and total P values were highest at class B site 8; average values were 0.76 mgN/ℓ and 0.046 mgP/ℓ respectively. These concentrations were concluded to be inorganic N and P associated with suspended solids (silt and sediment). Apparent violations of the class AA total nitrogen standard (>0.40 mgN/ℓ) were invalid because of the (NO_3+NO_2)-N data; average total N concentrations were 0.12 and 0.05 mgN/ℓ respectively for sites 5 and 6.

Ponape

Fourteen sites were sampled in the waters surrounding Ponape on January 8-10, 1980 (Figure 14). All sampling was done by boat. Site descriptions are:

1. DAWAHK; 40 m from a wide mangrove belt on a shallow reef flat platform; extensive coral growth; numerous birds in area; surrounding water deep murky green (Pristine area).

Table 22. Physical characteristics at Moen/Dublon sampling sites.

	SITE	TTPI CLASS	SAMPLING TIME			TIDE			DEPTH OF SITE (m)			SECCHI (m)			CURRENT DIRECTION (RELATIVE VELOCITY)			WIND DIRECTION (cf. Speed-Kts)		
TRUK	1	A	1000	0845	0915	WR	WR	WR	4.5	3	3				SSW(S)	S (M)	WNW(S)	ESE(5)	ENE(4)	NE(5)
MOEN AND	2	A	1040	0915	0945	WR	WR	WR	15	55.5	18.5	10.0	13.0	16.5	WNW(M)	SSW(W)	WNW(M)	ENE(5)	ENE(3)	NE
DUBLON	3	B	1100	0935	1010	WR	WR	WR	7.5	0.8	0.5				W (W)	WSE(S)	NW (W)	ENE(5)	ENE(4)	ENE(5)
January 2-4	4	AA	1130	1000	1030	WR	WR	WR	2	1	0.5				SW (W)	WSW(M)	SW (W)	ENE(6)	ENE(7)	ENE(5)
1980	5	AA	1205	1030	1100	WR	WR	WR	0.5	1	0.5				W (M)	SW (M)	WSW(S)	ENE(8)	ENE(7)	ENE(5)
	6	AA	1230	1045	1125	WR	WR	WR	1	0.5	0.5				WSW(M)	W (W)	WSW(W)	ESE(2)	ENE(2)	NE (2)
	7	B	1245	1105	1140	WR	WR	WR	0.7	3	3				SW (S)	WSW(M)	W (M)	ENE(7)	ENE(5)	ESE(5)
	8	B	1330	1130	1210	WR	WR	WR	1	0.8	0.8	0.5	0.8	0.8	W (M)	W (W)	W (W)	ENE(5)	ENE(2)	ESE(7)
	9	AA	1400	1200	1230	WR	WR	WR	1	1	0.5				W (S)	SW (S)	WNW(M)	ESE(6)	ENE(7)	NE (7)
	10	B	1600	1330	1300	NEAP	WR	WR	4	4	4				SSW(M)	W (M)	WNW(S)	ENE(7)	ESE (7)	ESE(7)

TIDE:
WR - Weak rising
NEAP - 30 min. before and after tide change

CURRENT VELOCITY:
(W) weak
(M) moderate
(S) strong

Table 23. Physical and bacteriological characteristics of water at Moen/Dublon sampling sites.

STATION	TTPI CLASS	WATER TEMPERATURE °C			TURBIDITY NTU			pH			DISSOLVED OXYGEN mg/ℓ			SALINITY o/oo			TOTAL COLIFORM #/100 mℓ			FECAL COLIFORM #/100 mℓ		
1	A	27.9	28.0	28.4	1.8	1.3	0.2	8.10	8.1	8.1	6.63	6.09	6.45	32	32	32	52	9	3	3	12	3
2	A	28.6	28.2	28.7	1.4	0.3	0.2	8.20	8.1	8.0	6.81	6.81	8.06	33	32	32	18	9	3	2	8	2
3	B	27.9	27.8	29.0	1.4	1.6	0.9	8.20	8.0	8.0	7.34	8.78	8.96	32	28	30	14	72	3	3	48	2
4	AA	28.3	28.5	29.8	1.5	0.6	0.5	8.15	8.0	8.3	9.31	9.14	12.12	32	30	31	0	2	0	0	2	2
5	AA	27.9	28.3	29.0	2.0	1.8	1.6	8.00	8.0	7.9	6.99	6.45	6.63	32	30	28	3	40	17	0	22	4
6	AA	28.6	29.3	30.0	1.3	0.5	0.4	8.28	8.2	8.2	9.49	10.03	10.57	33	32	32	2	0	36	0	0	5
7	B	28.5	29.8	29.3	1.0	0.3	0.5	8.30	8.1	8.2	8.78	8.78	9.85	32	32	33	143	5	32	17	1	7
8	B	27.4	28.4	30.0	9.4	6.2	4,5	7.90	8.2	8.1	7.52	8.06	8.96	25	17	22	1740	2800	140	1090	2400	70
9	AA	28.5	28.1	30.0	1.2	0.4	0.4	8.10	8.2	8.2	8.24	8.24	10.21	33	33	33	10	0	1	2	0	0
10	B	28.4	28.7	28.8	1.1	0.6	0.6	8.15	8.2	8.1	7.70	7.34	6.99	33	32	33	3	141	6	0	68	10

Underscored data represents violations of TTPI standards.

Table 24. Chemical characteristics of water at Moen/Dublon sampling sites.

STATION	TTPI CLASS	PO_4-P mg/l			TOTAL P mg/l *				$(NO_3 + NO_2)$-N mg/l			NH_3-N mg/l			TKN mg/l			TOTAL N mg/l **				TSIN*** mg/l		
1	A	.004	.007	.005	.050	.009	.014	.006	.017	.008	.35	.149	.051	.021	.03	.12	.01	.75	.05	.13	.16	.166	.059	.52
2	A	.004	.006	.004	.050	.004	.006	.006	.011	.006	.35	.064	.039	.027	.07	.10	.02	.75	.08	.11	.12	.075	.045	.38
3	B	.005	.004	.000	.100	.005	.009	.003	.012	.010	.38	.068	.053	.016	.24	.08	--	1.50	.25	.09	--	.080	.063	.44
4	AA	.004	.004	.000	.025	.008	.006	.009	.011	.011	.28	.072	.085	.016	.06	.10	.11	.40	.07	.21	.39	.083	.096	.30
5	AA	.006	.007	.005	.025	.010	--	.009	.018	.018	.32	.047	.022	.033	.07	.12	.09	.40	.09	.14	.41	.065	.040	.35
6	AA	.005	.007	.007	.025	.005	.007	.008	.014	.010	.38	.017	<.010	.048	.08	<.01	.34	.40	.09	.01	.72	.031	.015	.43
7	B	.004	.004	.004	.100	.004	.006	--	.010	.010	.02	.069	.074	.058	.07	.07	.09	1.50	.08	.08	.11	.029	.036	.08
8	B	.005	.007	.007	.100	.030	.092	.016	.020	.42	.01	.062	.028	.040	.24	.09	.26	1.50	.26	.51	.27	.082	.45	.05
9	AA	.006	.007	.005	.025	.011	.007	.003	.014	.32	<.01	.054	.086	.045	.09	.08	.07	.40	.10	.40	.07	.068	.41	.05
10	B	.004	.009	.020	.100	.006	.009	.006	.008	.32	.41	.054	.027	.039	<.01	.08	.04	1.50	.01	.40	.45	.062	.45	.45

* TTPI standards for total phosphorus, mg/l.
**TTPI standards for total nitrogen, mg/l.
***Total soluble inorganic nitrogen.
Underscored data represent violations of TTPI standards.

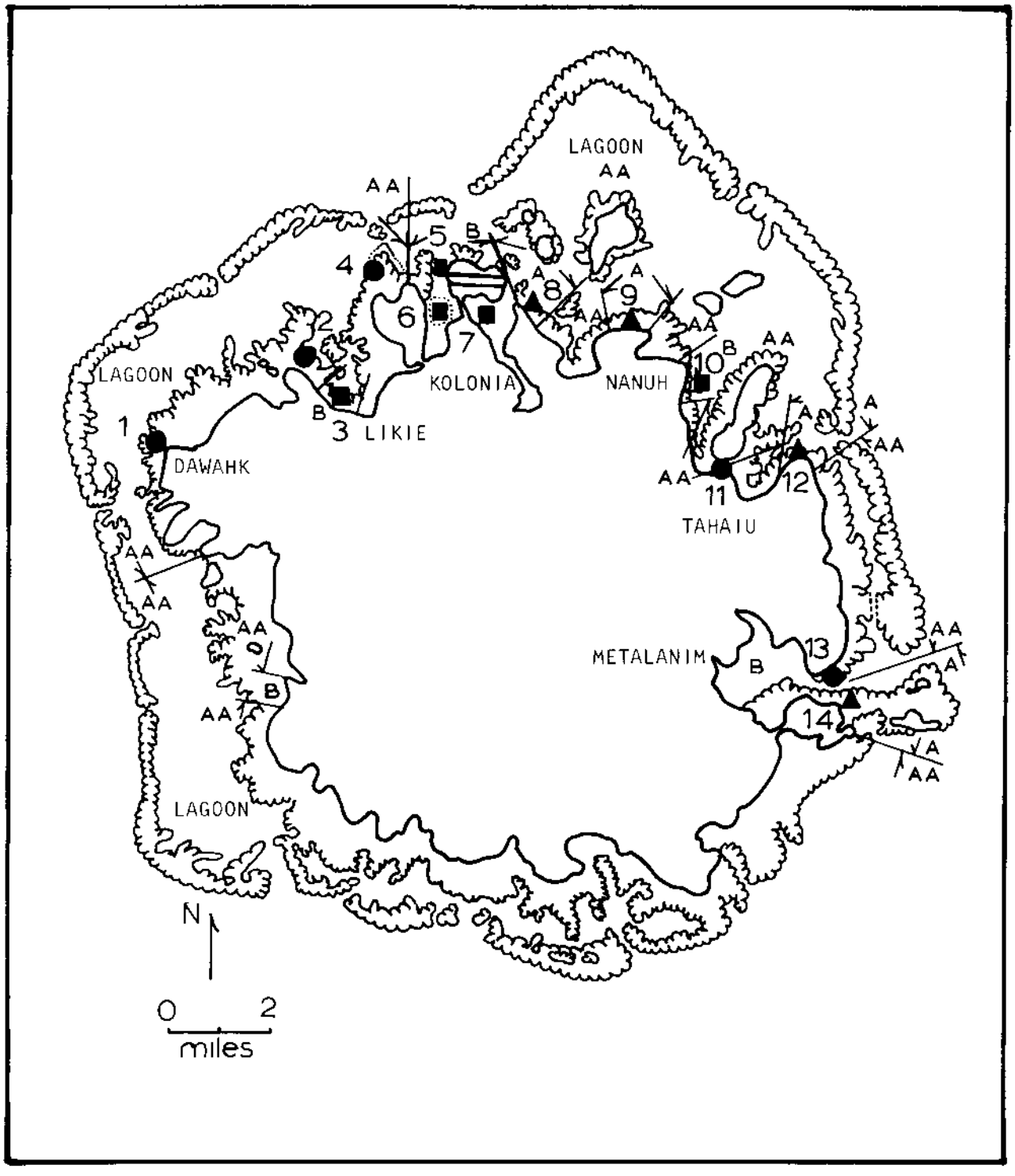

Figure 14. Sampling sites at Ponape. The circles are AA waters, the triangles are A waters and the squares are B waters.

2. MWANG; 50 to 75 m from mangrove on edge of a large shallow reef flat; extensive coral growth (Pristine area).

3. LIKIE; inside of complex patch reef system at old dredge and dock site, sampled off dock 10 to 15 m with drop off at 20 m; few inshore mangroves; heavy bird gathering at end of dock; low amount of surface debris with murky surrounding waters.

4. DEOLEITIK; along edge of narrow fringing reef at point, 40 m from mangroves; shallow-rocky platform with good coral development; water generally clean with low to no debris.

5. DEKETICK; 30 m from end of airport runway on small patch reef surrounded by deep water; slight rotten odor in area; few inshore mangroves; construction activities near end of runway.

6. MWALOK; along edge of patch reef in center of harbor near sewer outfall; deep green to very murky around area; river influence with low to heavy debris.

7. KOLONIA; 75 m from shore near old wrecked barge out from the Mobil fueling station; shallow, silt to fine sand bottom; river influence with water murky to extremely murky; moderate to heavy debris; traces of oil on surface; near edge of small boat lane.

8. TUMENBEL; 10 m off end of iron piling dock with building; deep water drop off 15 m from dock; next to small boat lane; water generally clean with low debris.

9. MANDOLMAL; below Village Hotel, 50 m from shore on large shallow fringing reef platform; water clean with low to no debris.

10. NANUH; 10 m off end of long (ca. 100 m) stone dock; deep drop off; rock bottom; water clean with low debris.

11. TAKAIU; shallow reef flat between small island and Ponape, in small boat channel; heavy mangrove influence; scattered corals with seagrasses predominant; small kids fishing in area; water muddy with low debris.

12. AROU; edge of 75 m wide reef flat platform at mangrove lined point; rocky bottom with few scatter large corals, slight green tint to water with low debris.

13. BAHNTAINUE; north side of Metalanim Harbor 75 m from small mangrove islands on wide shallow fringing reef flat, 150 m from mangrove lined shore; area receives swell from pass; sandy bottom with seagrass; water clean with low to no debris.

14. IENWEN; south side of Metalanim Harbor, 30 m from end of dock in seagrass beds; water murky green with moderate to heavy debris.

Sample time, tide, depth of site, Secchi depth, water current and wind direction data are presented in Table 25. All sites except two (sites 8 and 10) were shallow. Differences in station depths for sites 3, 8, 10 and 14 were due to boat drift. Waters were generally clear except for sites 6, 12 and 14 (appearance of green color indicative of phytoplankton) and for sites 7 and 11 (murky brown color indicative of suspended silt and sediments). Secchi depths equal to bottom depths were observed for class B sites 6 (near sewer outfall) and 7 (Kolonia Harbor).

Physical, chemical and bacteriological data are listed in Tables 26 and 27. Higher turbidities (January 10), generally higher coliform concentrations (January 9 and 10), and lower salinities and water temperatures (January 10) were attributed to heavy rains on January 8 and 9 (1.47 and 1.72 inches respectively, Table 8). Rainfall conditions in the mountains (although not quantified) were estimated to be extremely heavy on January 9. Freshwater inputs from rivers in the area of sites 6 and 7 account for the excessive increases in turbidity and the lower salinities measured at these sites. Dissolved oxygen (D.O.) concentration was less than the class AA standard for site 1 (January 9); however, this station was concluded to not be in violation of minimum D.O. levels (<6.0 mg/ℓ) because the average D.O. concentration of site 1 was 6.57 mg/ℓ.

Violations of class B fecal coliform concentrations were quantified at site 7 (Kolonia Harbor) for January 8-10. The high total and fecal coliform levels indicate the existence of a health hazard in this area (average values were 4860 total coliform/100 mℓ and 2967 fecal coliform/100 mℓ). Average total and fecal coliform concentrations were <61/100 mℓ for all other sites except site 6 where averages were measured as 377 total coliform/100 mℓ and 273 fecal coliform/100 mℓ.

Total P concentrations were $\leq$0.013 mgP/ℓ for all sites except site 7 (average total P of 0.019 mgP/ℓ). Total N concentrations were low for all Ponape stations (Table 27).

Kosrae

Seven sites were sampled in the marine waters surrounding Kosrae (Figure 15) on January 23-25, 1980. Sites 1 and 2 were sampled by boat; the remaining five sites were shallow and sampled by wading out from shore. The sampling sites were:

1. OKAT; north side of channel, 50 m from mangroves; receives outflow from mangroves with heavy debris; silty dark sand bottom with scattered seagrasses; inshore area appears to be a rookery for seabirds; numerous small fish in area.

Table 25. Physical characteristics at Ponape sampling sites.

	SITE	TYPE CLASS	SAMPLING TIME			TIDE			DEPTH OF SITE (m)			SECCHI (m)			CURRENT DIRECTION (RELATIVE VELOCITY)	WIND DIRECTION (cm,Speed-Kts)
PONAPE	1	AA	1200	1100	1110	WR	WF	WF	1	0.5	0.5				NW (S) WSW(M) S (S)	S (4) NE (1) ENE(1)
January 8-10	2	AA	1250	1200	1210	WR	NEAP	WF	1	1	0.5				NNE(M) NE (M) S (S)	NE(1) NNE(6) NNE(8)
1980	3	B	1305	1215	1230	WR	NEAP	WF	1	1	2				N (S) W (M) E (M)	NNW(2)NNE(6) NNE(8)
	4	AA	1330	1245	1300	WR	WR	NEAP	1	1	0.5				SW (M) W (M) SW (M)	NE (3)NE (6) NNE(9)
	5	B	1100	1005	1010	WF	WF	WF	1	0.5	0.5				WNW(M) SW (M) SSW(M)	ENE(1)ENE(6) NE (3)
	6	B	1045	0950	1000	WF	WF	WF	1.2	0.5	0.5	-	-	0.5	NNW(M) SSW(M) W (M)	ENE(1)NE (4) NNE(1)
	7	B	1030	0930	0940	WF	WF	WF	0.5	0.5	0.5	-	0.5	0.5	E (M) SSW(F) WNW(M)	ENE(1)NE (4) NNE(7)
	8	A	1810	1715	1745	NEAP	WR	WR	6	6	3				E (M) SSW(S) NNW(S)	E (1)ENE(4) ENE(1)
	9	A	1750	1700	1720	WR	WR	WR	0.5	0.5	0.5				NW (M) W (M) NW(S)	NE (1)NE (1) ENE(1)
	10	B	1710	1630	1655	WR	WR	WR	2.5	6	3				E (M) S (M) S (M)	NE (1)NE (5) NE (5)
	11	AA	1700	1615	1630	WR	WR	WR	0.5	0.5	0.5				WSW(S) SSW(M) WSW(M)	NE (1)ENE(1) ENE(3)
	12	A	1645	1545	1600	WR	WR	WR	0.5	0.5	0.5				WSW(M) SW (M) WSW(M)	NE (1)ENE(1) ENE(5)
	13	AA	1600	1445	1500	WR	WR	WR	0.5	0.5	0.5				NNW(M) N (M) WSW(M)	ENE(1)ENE(6) ENE(4)
	14	A	1530	1500	1515	WR	WR	WR	3	1	1				W (M) W (M) WSW(M)	ENE(1)ENE(4) ENE(6)

TIDE:
WF - Weak falling
WR - Weak rising
NEAP - 30 min. before and after tide change

CURRENT VELOCITY:
(W) Weak
(M) Moderate
(S) Strong

Table 26. Physical and bacteriological characteristics of water at Ponape sampling sites.

STATION	TTPI CLASS	WATER TEMPERATURE °C			TURBIDITY NTU			pH			DISSOLVED OXYGEN mg/ℓ			SALINITY o/oo			TOTAL COLIFORM #/100 mℓ			FECAL COLIFORM #/100 mℓ		
1	AA	29.7	29.4	28.9	0.6	0.6	2.4	8.2	8.1	7.80	8.06	4.84	6.81	32	31	30	0	332	0	0	16	33
2	AA	29.7	29.0	28.4	0.8	0.6	2.5	8.2	8.1	8.10	8.60	9.14	8.96	29	30	26	0	5	28	0	6	2
3	B	30.9	29.1	28.9	0.7	1.9	3.6	8.2	7.8	8.00	8.78	6.27	6.63	31	29	24	0	26	26	0	130	12
4	AA	28.9	28.5	29.5	0.5	0.6	3.0	8.1	8.1	8.28	7.16	7.52	13.11	34	32	31	0	15	10	0	75	2
5	B	28.6	28.4	27.8	0.6	0.4	2.7	8.2	8.1	7.90	6.81	6.45	6.62	32	32	26	20	26	57	0	9	24
6	B	28.9	28.9	28.2	1.1	1.9	4.5	8.0	8.1	8.00	5.91	6.45	5.73	29	30	8	30	520	580	120	380	120
7	B	28.0	27.3	25.9	2.9	2.5	13.0	8.2	8.1	8.30	6.81	6.99	7.34	15	14	2	780	1600	12200	2140	760	6000
8	A	28.8	28.6	28.1	0.6	0.6	1.8	7.9	8.1	8.10	7.52	7.34	6.99	32	32	28	0	122	59	0	156	26
9	A	30.4	29.1	28.8	0.8	1.6	2.3	8.3	8.0	8.16	11.11	7.34	7.88	31	30	29	11	0	20	5	20	0
10	B	31.2	29.0	28.9	0.9	0.8	1.1	8.1	8.1	8.18	7.34	7.52	8.24	30	32	31	135	4	3	22	3	0
11	AA	30.5	29.3	29.1	0.7	1.5	2.9	8.1	8.0	7.90	7.88	6.81	7.16	29	29	24	2	9	13	0	0	18
12	A	30.3	28.8	28.6	0.4	0.7	1.6	8.3	8.1	8.12	10.21	7.52	7.34	32	33	32	0	9	18	0	0	2
13	AA	30.4	30.8	29.7	0.8	0.7	1.4	8.1	8.5	8.40	7.70	12.72	10.57	25	30	29	6	11	7	0	0	0
14	A	29.8	30.2	29.2	0.8	0.7	1.6	8.2	8.4	8.20	8.78	9.31	7.34	30	28	25	0	8	29	0	0	1

Underscored data represent violations of TTPI standards.

Table 27. Chemical characteristics of water at Ponape sampling sites.

STATION	TTPI CLASS	PO_4-P mg/ℓ			TOTAL P mg/ℓ *				$(NO_3 + NO_2)$-N mg/ℓ			NH_3-N mg/ℓ			TKN mg/ℓ			TOTAL N mg/ℓ **				CHLOROPHYLL a mg/m³		
1	AA	.005	.007	.004	.025	.005	--	.004	.009	.009	.013	.032	.071	.069	.12	--	.05	.40	.13	--	.06	.071	.060	.052
2	AA	.004	.007	.003	.025	.004	--	.003	.012	.011	.006	.046	.070	.070	.08	--	.03	.40	.09	--	.06	.043	.084	.075
3	B	.003	.005	.004	.100	.009	.005	.006	.022	.018	.014	.055	.077	.094	.07	.13	.10	1.50	.09	.15	.11	.077	.095	.106
4	AA	.004	.007	.004	.025	--	.007	.004	.011	.008	.005	.062	.062	.014	--	.27	.06	.40	--	.28	.06	.078	.070	.039
5	B	.004	.007	.006	.100	--	.007	--	.011	.010	.013	.037	.077	.047	--	.09	--	1.50	--	.10	-	.048	.087	.060
6	B	.006	.006	.011	.100	--	.009	.011	.015	.005	.022	.066	.085	.011	--	.06	.15	1.50	--	.06	.17	.081	.090	.053
7	B	.004	.008	.011	.100	.024	.012	.021	.025	.008	.012	.038	.102	.047	.06	.15	.15	1.50	.08	.16	.16	.063	.110	.059
8	A	.010	.007	.007	.050	.010	.007	.007	.017	.009	.011	.078	.078	.053	.06	.07	<.01	.75	.08	.09	.01	.085	.087	.066
9	A	.006	.004	.007	.050	.006	--	.007	.021	.017	.014	.030	.052	.024	.12	--	.10	.75	.19	--	.11	.054	.069	.038
10	B	.006	.023	.006	.100	.012	--	--	.012	.012	.009	.070	.052	.034	.49	--	--	1.50	.50	--	--	.082	.044	.067
11	AA	.004	.005	.008	.025	--	.008	.013	--	.012	.018	.031	.029	.048	--	.08	.14	.40	--	.09	.16	-	.036	.066
12	A	.006	.007	.010	.050	.006	.007	--	--	.002	.013	.095	.023	.030	.09	.06	--	.75	--	.06	--	--	.025	.061
13	AA	.004	.007	.006	.025	--	.007	.008	.011	.006	.008	.031	.055	.021	--	.09	.14	.40	--	.10	.15	.062	.061	.029
14	A	.004	.007	.006	.050	.009	.007	.006	.011	.006	.024	.094	.069	.045	.08	.10	.30	.75	.09	.11	.12	.105	.075	.069

* TTPI standards for total phosphorus, mg/ℓ.
**TTPI standards for total nitrogen, mg/ℓ.
***Total soluble inorganic nitrogen.

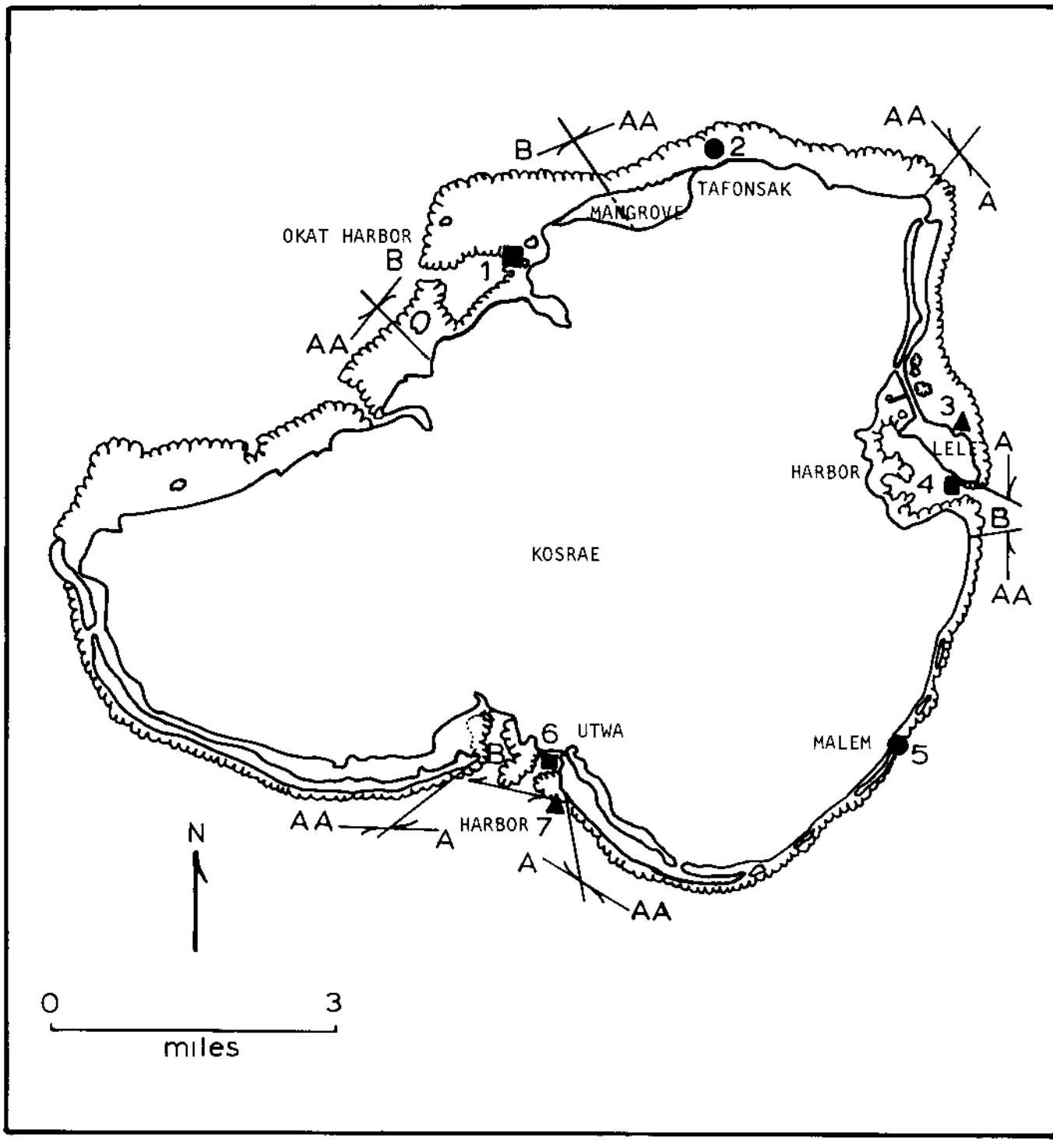

Figure 15. Sampling sites at Kosrae. The circles are AA waters, the triangles are A waters and the squares are B waters.

2. TAFONSAK; 50 m from shore on moderately shallow reef flat which is ca. 175 m wide; seagrass beds with clean biogenic sands; heavy debris line near shore; heavily used by people.

3. LELE (reef flat); 50 m onto reef flat at rock break water; heavy seagrass/pavement area; area exposes at low tides; low debris; moderately used by people.

4. LELE (harbor); 30 m onto fringing reef flat near entrance to harbor at edge of deep channel; near red buoy sampled over hard pavement with few scattered corals; low to no debris; heavy outflow current with strong surge.

5. MALEM; 40 m from shore and ca. 20 m from reef margin near center of village; hard pavement that exposes completely at low tide; little algal growth and few scattered corals; no debris.

6. UTWA (village); 150 m from shore and 250-300 m from river mouth on sand spit; mangrove development at river area; sediments are primarily terrigenous; low debris at sampling area and heavy near shore; waters used for recreation.

7. UTWA (harbor entrance); 25 m from reef margin on west side of channel and 75 m from shore; inner reef flat exposes and outer portion receives surf splash; heavy surf zone; large boulders throughout area with numerous corals in area; water clean with no debris.

Sample time, tide, depth of site, water current and wind direction data are presented in Table 28. It is noted that all site depths were $\leq$1 m. Physical, chemical (D.O.) and bacteriological data are listed in Table 29. Class AA minimum dissolved oxygen (D.O.) concentrations were violated at sites 1 and 2; average D.O. levels were 5.19 and 5.55 mg/ℓ respectively. Class AA total coliform standard (<230/100 mℓ) was exceeded for all three days at site 2; average coliform concentrations for this site were 828 total coliform/100 mℓ and 548 fecal coliform/100 mℓ. Since this area is used for recreation, potential health hazard is estimated to be high. Site 4 (class B) fecal coliform concentration exceeded the standard (<400/100 mℓ) on January 23; the violation was not substantiated in the other samples for site 4. Average fecal coliform concentration (site 4) was 200/100 mℓ.

Nitrogen and phosphorus data are presented in Table 30. Total P concentrations were $\leq$0.017 mgP/ℓ for all sites except site 6 where the average total P level was measured as 0.033 mgP/ℓ. Corresponding orthophosphate phosphorus (PO_4-P) concentrations for site 6 were 0.010, 0.038 and 0.013 mg PO_4-P/ℓ. The average inorganic P concentration (excluding January 24 datum) was 0.012 mg PO_4-P/ℓ. It was assumed that the 0.038 mg PO_4-P/ℓ was not valid (possible contamination in sample bottle); therefore, this value will be excluded from subsequent data analysis.

Table 28. Physical characteristics at Kosrae sampling sites.

	SITE	TTPI CLASS	SAMPLING TIME			TIDE			DEPTH OF SITE (m)			CURRENT DIRECTION (RELATIVE VELOCITY)	WIND DIRECTION (ca.Speed-Kts)
KOSRAE	1	AA	0845	0745	0745	SF	NEAP	NEAP	1	1	1	SW (W) W (W) SSW(W)	NE (2) ENE(3) NE (1)
January 23-25	2	AA	0830	0805	0815	SF	SF	SF	0.5	0.5	0.5	W (M) SW (M) SSW(W)	ENE(3) ENE(5) NE (2)
1980	3	A	1005	0930	1000	SF	SF	SF	0.5	0.7	1	W (W) WSW(M) WSW(W)	NE (4) ENE(4) NE (2)
	4	B	1020	0940	1020	SF	SF	SF	0.7	1	1.5	SE (W) SW (S) SSW(S)	NE (4) NE (5) ENE (4)
	5	AA	1110	1020	1100	SF	SF	SF	0.2	0.3	0.5	N (W) ENE(F) E (M)	NE (4) ENE(6) NE (3)
	6	B	1200	1100	1120	SF	SF	SF	0.5	1	1	S (W) SSW(M) E (M)	NE (2) NE (2) ENE(1)
	7	A	1215	1115	1140	SF	SF	SF	0.5	1	1	W (M) ENE(W) ENE (W)	NE (2) ENE(2) ENE(1)

TIDE:
SF - Strong falling
NEAP - 30 min, before and after tide change

CURRENT VELOCITY:
(W) Weak
(M) Moderate
(S) Strong

Table 29. Physical and bacteriological characteristics of water at Kosrae sampling sites.

STATION	TTPI CLASS	WATER TEMPERATURE °C			TURBIDITY NTU			pH			DISSOLVED OXYGEN mg/l			SALINITY o/oo			TOTAL COLIFORM #/100 ml			FECAL COLIFORM #/100 ml		
1	AA	27.5	27.5	28.4	0.7	0.8	0.5	7.80	7.90	7.75	5.22	5.73	6.63	32	33	33	195	39	26	6	2	1
2	AA	27.2	26.4	26.4	1.6	0.6	0.5	7.95	7.85	7.90	7.16	5.91	3.58	32	32	31	255	1040	1200	93	540	1040
3	A	28.6	28.7	28.6	0.4	0.5	0.4	8.30	8.05	8.15	8.06	8.42	7.70	33	33	33	36	31	51	0	0	21
4	B	28.9	28.8	29.0	2.6	0.4	0.3	8.30	7.95	8.20	8.06	7.34	7.70	30	34	33	1080	30	0	600	0	0
5	AA	29.3	28.7	29.2	0.3	0.3	0.4	8.38	8.10	8.25	9.31	7.52	8.06	33	34	34	32	60	8	0	0	0
6	B	28.5	28.8	29.4	1.0	2.2	1.8	7.90	8.00	8.20	5.37	6.27	6.45	24	30	33	540	330	26	180	122	6
7	A	28.9	29.2	29.4	1.2	0.2	0.3	8.20	8.10	8.25	8.24	8.60	10.21	33	33	34	190	160	4	8	1	0

Underscored data represent violations of TTPI standards.

Table 30. Chemical characteristics of water at Kosrae sampling sites.

STATION	TTPI CLASS	PO_4-P mg/ℓ			TOTAL P mg/ℓ *			$(NO_3 + NO_2)$-N mg/ℓ			NH_3-N mg/ℓ			TKN mg/ℓ			TOTAL N mg/ℓ **				TSIN *** mg/ℓ		
1	AA	.005	.004	.006	.025	.012	.006	.013	.014	.003	.009	.023	.039	.094	.20	.22	.17	.40	.21	.22	.18	.037	.042	.103
2	AA	.007	.005	≤.009	.025	.015	.013	.009	.012	.001	.017	.032	.022	.079	.17	.17	.14	.40	.18	.17	.16	.044	.023	.096
3	A	.002	.004	.011	.050	.004	.008	.011	.006	.002	.012	.032	.043	.062	.20	.11	.17	.75	.21	.11	.18	.038	.045	.074
4	B	.007	.003	.007	.100	.017	.010	.007	.008	.000	.014	.040	.040	.065	.08	.10	.30	1.50	.09	.10	.31	.048	.040	.079
5	AA	.004	.002	.006	.025	.013	.007	.006	.008	.002	.012	.023	.039	.023	.16	.11	.08	.40	.17	.11	.09	.031	.041	.035
6	B	.010	.038	.013	.100	.045	.038	.016	.015	.001	.018	.062	.042	.060	.19	.16	.40	1.50	.21	.16	.42	.077	.043	.078
7	A	.005	.005	.007	.050	.005	.006	.012	.015	.007	.016	.035	.085	.066	.10	.30	.19	.75	.12	.31	.21	.050	.092	.082

* TTPI standards for total phosphorus, mg/ℓ.
**TTPI standards for total nitrogen, mg/ℓ.
***Total soluble inorganic nitrogen.

DISCUSSION

TTPI Baseline Marine Water Quality

Due to the lack of a representative number of samples collected at each site, no reliable statistical analysis can be performed on the individual values measured in this study. For this reason, arithmetic means (averages of three samples) were calculated for each site. Arithmetic means and ranges of values for the marine water quality parameters measured are presented in tabular form according to island groups and TTPI marine water classifications. Median values for most parameters were estimated utilizing probability distribution plots. A straight line on the probability plots indicates a normal distribution of measured (observed) values.

A two-way analysis of variance was performed on the mean values listed in Tables 31-41. Since only three measurements were taken at each site (a statistically insignificant number of samples), mean parameter values were analyzed for each island/class data set. It is noted that the class A waters of Majuro and Ebeye/Gugeegue are each represented by only one site. Tabulated rows of arithmetic means represent islands; whereas, columns represent TTPI marine water classifications. Variances of mean values for islands and for classifications were compared to the variance of mean values for all the data and statistically significant differences were analyzed at the five percent level ($p \leq 0.05$).

Water Temperature

Mean water temperatures are presented in Table 31. Variation of arithmetic mean temperatures was greater between islands than between classes, but the difference was not statistically significant. Mean water temperature for all data was 29.1°C. The data were plotted on probability paper (Figure 16) and the resultant median temperature (50% probability value) was 29.0°C. These values are in agreement with the mean literature value of 28.9°C (Tables 4 and 6). Background water temperature was concluded to be 29.0°C for TTPI marine waters.

pH

Analysis of variance for territorial pH values (Table 32) quantified minimum variability between classes and statistically significant differences between islands. Mean and median pH values were 8.12 and 8.09 respectively. Since the probability plot (Figure 17)

Table 31. Arithmetic means and ranges for water temperature (°C).

ISLAND	TTPI CLASS AA			TTPI CLASS A			TTPI CLASS B			TTPI ISLAND VALUES			
	$\bar{Y}$	(N)	Range	$\bar{Y}$	(N)	Range	$\bar{Y}$	(N)	Range	$\bar{Y}$	(N)	Range	Range of Means
MAJURO	30.3	(18)	28.1-33.6	29.5	(3)	29.2-29.8	29.5	(9)	29.0-30.0	30.0	(30)	28.1-33.6	29.5-30.3
EBEYE/GUGEEGUE	29.2	(15)	28.9-29.6	29.5	(3)	29.3-29.8	29.2	(9)	28.5-29.8	29.2	(27)	28.5-29.8	29.2-29.5
KOROR	29.7	(12)	28.9-31.5	29.7	(11)	29.0-31.2	29.3	(15)	29.0-29.8	29.5	(38)	28.9-31.5	29.3-29.7
YAP	28.6	(16)	26.5-31.0	28.3	(9)	27.5-30.0	29.2	(12)	27.0-31.0	28.7	(37)	26.5-31.0	28.3-29.2
MOEN/DUBLON	28.9	(12)	27.9-30.0	28.3	(6)	27.9-28.7	28.7	(12)	27.4-30.0	28.7	(30)	27.4-30.0	28.3-28.9
PONAPE	29.5	(15)	28.4-30.8	29.2	(12)	28.1-30.4	28.7	(15)	25.9-31.2	29.1	(42)	25.9-31.2	28.7-29.5
KOSRAE	27.8	(9)	26.4-29.3	28.9	(6)	28.6-29.4	28.9	(6)	28.5-29.4	28.4	(21)	26.5-29.4	27.8-28.9
TTPI CLASS VALUES	29.2	(97)	26.4-33.6	29.0	(50)	27.5-31.2	29.1	(78)	25.9-31.2	<u>29.1</u>	(225)	25.9-33.6	
RANGE OF MEANS	27.8-30.3			28.3-29.7			28.7-29.5						27.8-30.3

<u>Underscored</u> value represents arithmetic mean for all data.
$\bar{Y}$ = Mean
N = Number of samples

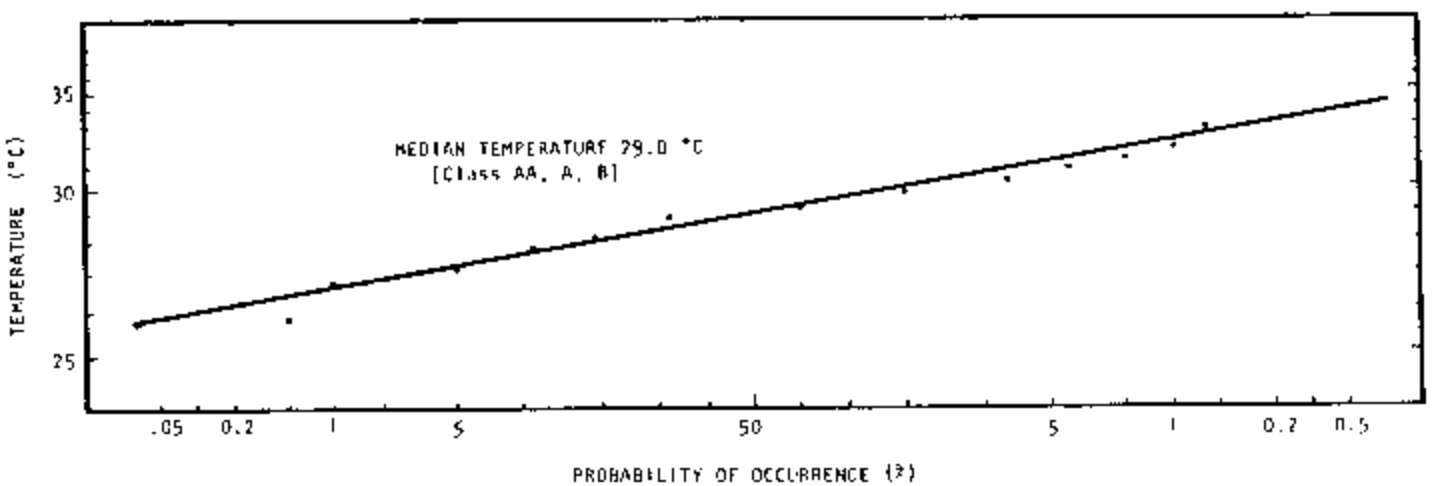

Figure 16. Probability distribution plot of temperature for all island and class data.

Table 32. Arithmetic means and ranges for pH.

ISLAND	TTPI CLASS AA			TTPI CLASS A			TTPI CLASS B			TTPI ISLAND VALUES			
	$\bar{Y}$	(N)	Range	$\bar{Y}$	(N)	Range	$\bar{Y}$	(N)	Range	$\bar{Y}$	(N)	Range	Range of Means
MAJURO	8.27	(18)	7.77-8.80	8.12	(3)	8.10-8.15	8.15	(9)	8.10-8.30	8.22	(30)	7.77-8.80	8.12-8.27
EBEYE/GUGEEGUE	8.28	(14)	8.10-8.40	8.33	(3)	8.30-8.40	8.25	(9)	8.20-8.35	8.28	(26)	8.10-8.40	8.25-8.33
KOROR	7.94	(12)	7.79-8.11	7.98	(12)	7.75-8.15	8.02	(15)	7.81-8.15	7.98	(39)	7.75-8.15	7.94-8.02
YAP	8.12	(16)	7.87-8.30	8.10	(9)	8.00-8.25	8.05	(12)	7.80-8.20	8.09	(37)	7.80-8.30	8.05-8.12
MOEN/DUBLON	8.13	(12)	7.90-8.30	8.10	(6)	8.00-8.20	8.12	(12)	7.90-8.30	8.12	(30)	7.90-8.30	8.10-8.13
PONAPE	8.13	(15)	7.80-8.50	8.16	(12)	7.90-8.40	8.09	(15)	7.80-8.30	8.12	(42)	7.80-8.50	8.09-8.16
KOSRAE	7.99	(9)	7.75-8.38	8.18	(6)	8.05-8.30	8.09	(6)	7.90-8.30	8.07	(21)	7.75-8.38	7.99-8.18
TTPI CLASS VALUES	8.14	(96)	7.75-8.80	8.11	(51)	7.75-8.40	8.10	(78)	7.80-8.35	<u>8.12</u>	(225)	7.75-8.80	
RANGE OF MEANS	7.94-8.28			7.98-8.33			8.02-8.25						7.94-8.33

Underscored value represents arithmetic mean for all data.

$\bar{Y}$ = Mean

N = Number of samples

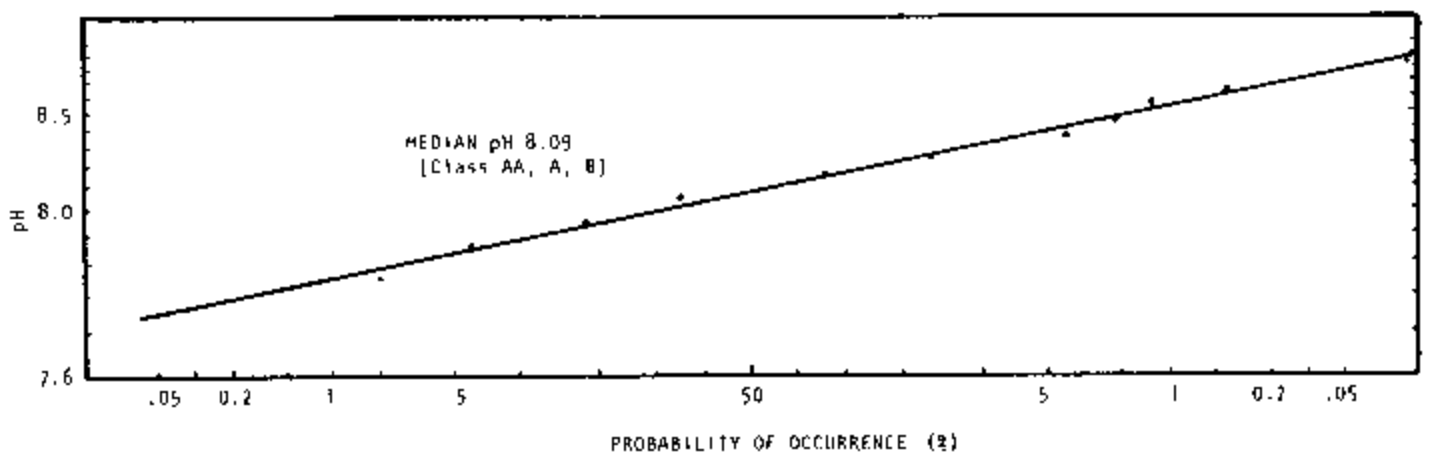

Figure 17. Probability distribution plot of pH for all island and class data.

of the territorial data was a straight line (indicative of a normal distribution of observed pH values), baseline pH was concluded to be 8.10. The range of mean pH values for all waters tested was 7.94 - 8.33 pH units. Average pH values taken from the literature were 8.00 (Table 4) and 8.24 (Table 6); these values are within the range of pH values measured in this research. It is recommended that the TTPI marine water quality pH standards be amended to: 8.10 ± 0.4 for all marine water classifications.

Salinity

Arithmetic means and ranges for the salinity data are presented in Table 33. Distribution of the data for all classes was skewed to the left (160 out of the total 223 samples had salinities of 32 - 34 °/oo). It was assumed that salinity concentrations in the marine environments surrounding the islands of Micronesia would not exhibit a normal distribution. Decreases in salinity measurements are attributed to rainfall and inputs of freshwater from the islands (both point and nonpoint sources). The range of mean values was 29 - 34 °/oo and the overall TTPI mean value was 32 °/oo (Table 33). The TTPI standard (Table 3) for salinity is the natural conditon ±10%. Utilizing the mean value of 32 °/oo as the baseline salinity, the means quantified in this study fall within the standard range: $29 \leq 32 \leq 35$ °/oo . It is noted that the baseline salinity is only applicable to sites without freshwater inputs and that the standard is not valid at any site on days of heavy rainfall. The mean values from the literature were 33 °/oo (Table 4) and 34 °/oo (Table 6).

It is anticipated that violations of salinity standards would be rare in Micronesia. It is estimated that the natural condition for site 7 on Ponape is 15 °/oo (range: 13.5 - 16.5 °/oo) . Salinity on January 10 at this site was 2 °/oo; this was attributed to heavy rainfall and therefore is not in violation of salinity standards.

Turbidity

Arithmetic mean turbidity values (Table 34) varied significantly between TTPI classes. This variation was attributed to the higher mean values in class B waters. The range of means for class AA and class A waters was 0.3 - 1.3 NTU; corresponding range of means for class B waters was 0.3 - 2.9 NTU. The arithmetic means for these two groups were 0.8 NTU (class AA, A) and 1.6 NTU (class B). Probability plots (Figures 18 and 19) represent distribution of data skewed to the right (108 of 148 samples [class AA, A] and 45 out of 78 samples [class B] had turbidity values between 0.2 and 0.9 NTU). Median turbidity values were 0.6 and 0.8 NTU (Figures 18 and 19, respectively). The probability plots for AA, A waters (Figure 18) and B waters (Figure 19) indicate that 20 percent of the time turbidity levels would equal or exceed 1.0 NTU for class AA, A and 2.0 NTU

Table 33. Arithmetic means and ranges for salinity (°/oo).

ISLAND	TTPI CLASS AA			TTPI CLASS A			TTPI CLASS B			TTPI ISLAND VALUES			
	$\bar{Y}$	(N)	Range	$\bar{Y}$	(N)	Range	$\bar{Y}$	(N)	Range	Y	(N)	Range	Range of Means
MAJURO	33	(18)	31-34	34	(3)	33-34	33	(9)	32-34	33	(30)	31-34	33-34
EBEYE/GUGEEGUE	34	(15)	33-34	34	(3)	34	34	(9)	33-34	34	(27)	33-34	34
KOROR	32	(12)	31-34	33	(12)	32-34	33	(15)	32-34	33	(39)	31-34	32-33
YAP	31	(16)	25-34	31	(9)	31-34	29	(11)	26-32	31	(36)	25-34	29-33
MOEN/DUBLON	32	(12)	28-33	32	(6)	32-33	32	(9)	28-33	32	(27)	28-33	32
PONAPE	29	(15)	24-34	30	(12)	25-32	30	(11)	24-32	30	(38)	24-34	29-30
KOSRAE	32	(9)	31-34	33	(6)	33-34	31	(6)	24-34	32	(21)	24-34	31-33
TTPI CLASS VALUES	32	(91)	24-34	32	(51)	25-34	32	(70)	24-34	<u>32</u>	(218)	24-34	
RANGE OF MEANS	29-34			30-34			29-34						29-34

Underscored value represents arithmetic mean for all data.
Y = Mean
N = Number of samples

Table 34. Arithmetic means and ranges for turbidity (NTU).

ISLAND	TTPI CLASS AA			TTPI CLASS A			TTPI CLASS B			TTPI ISLAND VALUES			
	$\bar{Y}$	(N)	Range	$\bar{Y}$	(N)	Range	$\bar{Y}$	(N)	Range	$\bar{Y}$	(N)	Range	Range of Means
MAJURO	0.6	(18)	0.2-2.7	0.3	(3)	0.2-0.3	0.3	(9)	0.2-0.3	0.5	(30)	0.2-2.7	0.3-0.6
EBEYE/GUGEEGUE	0.3	(15)	0.1-0.8	0.5	(3)	0.4-0.8	0.5	(9)	0.2-1.4	0.4	(27)	0.1-1.4	0.3-0.5
KOROR	0.7	(12)	0.4-2.4	0.8	(12)	0.4-1.6	0.7	(15)	0.3-1.2	0.7	(39)	0.3-2.4	0.7-0.8
YAP	1.0	(16)	0.3-2.1	0.6	(9)	0.3-1.5	2.9	(12)	0.9-13	1.5	(37)	0.3-13	0.6-2.9
MOEN/DUBLON	1.0	(12)	0.4-2.0	0.9	(6)	0.2-1.8	2.0	(12)	0.3-9.4	1.4	(30)	0.2-9.4	0.9-2.0
PONAPE	1.3	(15)	0.5-3.0	1.1	(12)	0.4-2.3	2.6	(15)	0.4-13	1.7	(42)	0.4-13	1.1-2.6
KOSRAE	0.6	(9)	0.3-1.6	0.5	(6)	0.2-1.2	1.4	(6)	0.3-2.6	0.8	(21)	0.2-2.6	0.5-1.4
TTPI CLASS VALUES	0.8	(97)	0.1-3.0	0.8	(51)	0.2-2.3	1.6	(78)	0.2-13	<u>1.1</u>	(226)	0.1-13	
RANGE OF MEANS	0.3-1.3			0.3-1.1			0.3-2.9						0.3-2.9

Underscored value represents arithmetic mean for all data.
$\bar{Y}$ = Mean
N = Number of samples

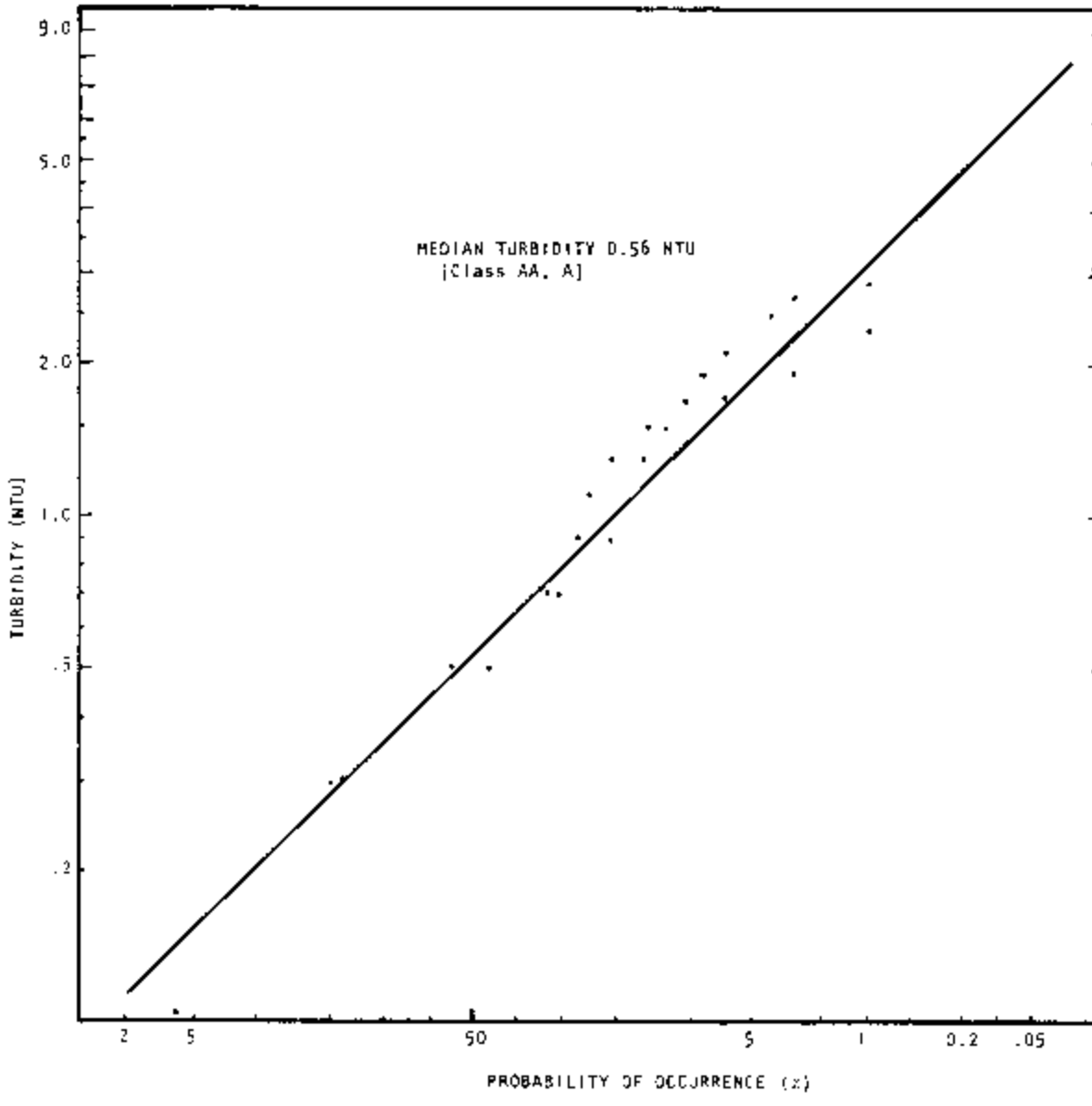

Figure 18. Probability distribution plot of turbidity for all class AA and A waters.

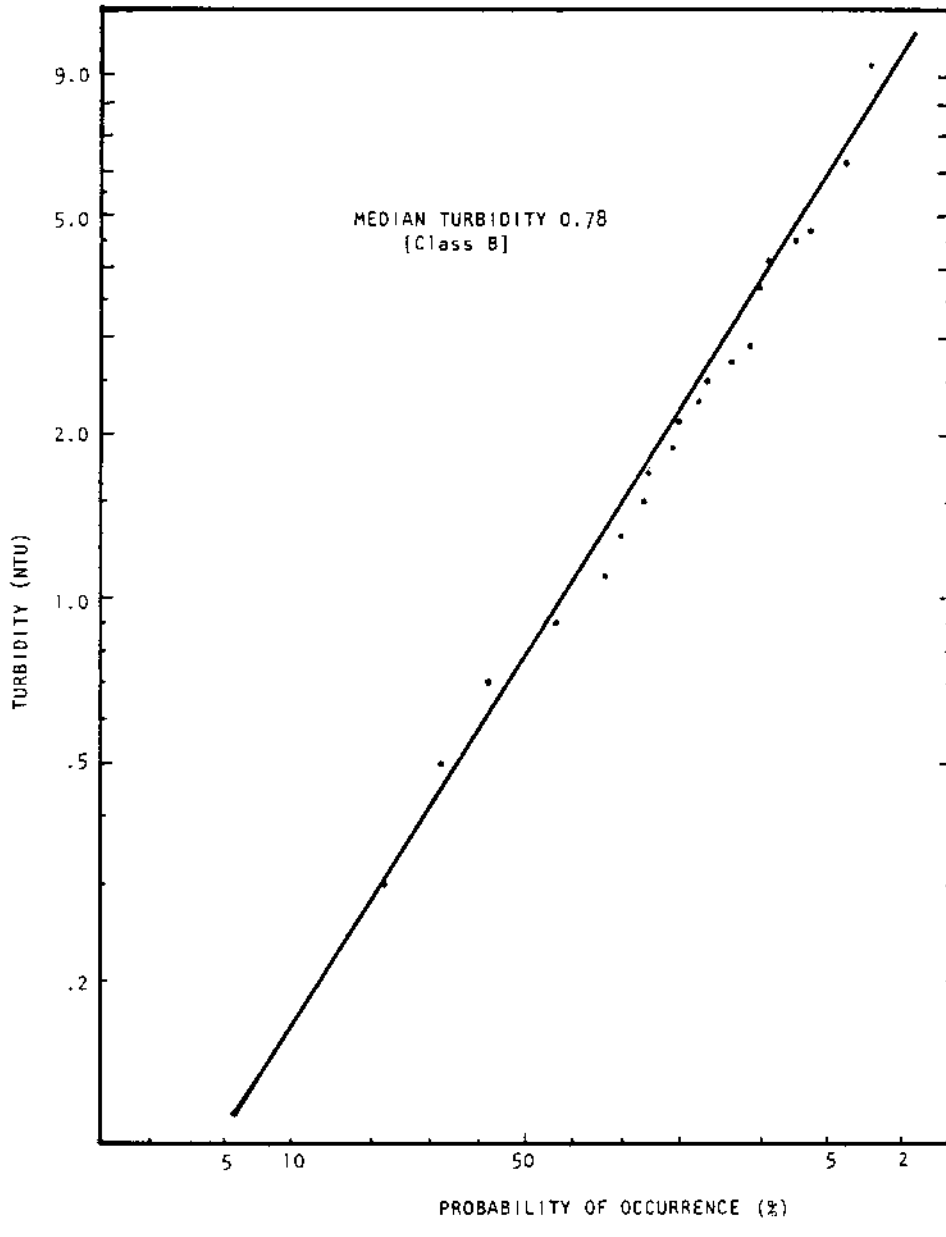

Figure 19. Probability distribution plot of turbidity for all class B waters.

for class B waters. Since the distributions of observed data were skewed, less importance was attributed to the arithmetic mean values; therefore, median values were utilized as estimates of baseline turbidity. Literature values for class AA waters were 0.5 NTU (Table 1) and 0.4 NTU (Table 6); the literature value for class B waters was 0.4 NTU (Table 1). These mean values were lower than the mean turbidity values observed in this study and substantiated the use of median values for estimates of natural conditions of turbidity in the TTPI.

Turbidity values of the marine waters surrounding the islands in Micronesia are affected by inputs of silt and sediments from the land masses. It is imperative that a minimum of five samples be gathered at any one site in order to identify a violation of turbidity standards. These data should not include measurements which are affected by heavy rainfall. Turbidity standards established in this study will apply to TTPI marine waters generally, and it is realized that isolated areas in the territory will have turbidities in excess of these limits. Special cases will have to be examined separately, on an individual basis, in order to evaluate actual baseline turbidity values.

Violations of turbidity standards are relevant only when associated with specific human activities (construction, land clearing). Environmental impact assessments are required for these man-made perturbations; point sources of silt and sediment pollution should be identified and related to specific activities.

Dissolved Oxygen

Arithmetic means and ranges of dissolved oxygen (D.O.) concentrations are presented in Table 35. No statistically significant differences were quantified for these mean values when assessed by islands or classes. The mean value and range of D.O. values were 7.20 mg/ℓ and 4.86 - 9.21 mg/ℓ, respectively. The probability distribution plot for all data (normal distribution) is represented in Figure 20. Median D.O. value was 6.70 mg/ℓ, which is in agreement with the literature data (6.3 mg/ℓ: Table 4; 6.78 mg/ℓ: Table 6). Utilizing mean and median concentrations quantified in this study, territorial baseline D.O. levels were estimated to be 6.95 mg/ℓ for all classes.

Violations of the minimum D.O. standards (Table 3) were observed at: Koror class AA site 2 (average: 5.75 mg/ℓ); Kosrae class AA sites 1, 2 (averages: 5.19 and 5.55 mg/ℓ).

Total and Fecal Coliform

Total and fecal coliform bacteria are organisms which indicate

Table 35. Arithmetic means and ranges for dissolved oxygen (mg/ℓ).

ISLAND	TTPI CLASS AA			TTPI CLASS A			TTPI CLASS B			TTPI ISLAND VALUES			
	$\bar{Y}$	(N)	Range	$\bar{Y}$	(N)	Range	$\bar{Y}$	(N)	Range	$\bar{Y}$	(N)	Range	Range of Means
MAJURO	8.62	(12)	6.32-12.99	5.86	(2)	5.66-6.06	5.98	(6)	5.60-6.28	7.55	(20)	5.60-12.99	5.86-8.62
EBEYE/CUGEEGUE	6.72	(15)	6.20-7.30	9.21	(3)	8.20-9.82	7.21	(9)	5.98-8.32	7.16	(27)	5.98-8.32	6.72-9.21
KOROR	6.06	(12)	5.07-8.11	6.32	(12)	5.42-8.30	4.86	(15)	4.85-7.91	5.68	(39)	4.85-8.30	4.86-6.32
YAP	7.28	(16)	5.16-10.28	6.97	(9)	5.36-8.48	7.26	(12)	5.67-9.68	7.20	(37)	5.16-10.28	6.97-7.28
MOEN/DUBLON	8.95	(12)	6.45-12.12	6.81	(6)	6.09-8.06	8.26	(12)	7.34-9.85	8.25	(30)	6.09-12.12	6.81-8.95
PONAPE	8.33	(15)	4.84-12.72	8.22	(12)	6/99-11.11	6.93	(15)	5.73-8.78	7.80	(42)	4.84-12.72	6.93-8.33
KOSRAE	6.35	(9)	3.22-9.31	8.54	(6)	7.70-10.21	6.87	(6)	5.37-8.06	7.12	(21)	3.22-10.21	6.35-8.54
TTPI CLASS VALUES	7.50	(91)	3.22-12.99	7.37	(50)	5.36-11.11	6.73	(75)	4.85-9.85	<u>7.20</u>	(216)	3.22-12.99	
RANGE OF MEANS	6.06-8.95			5.86-9.21			4.86-8.26						4.86-9.21

Underscored value represents arithmetic mean for all data.
$\bar{Y}$ = Mean
N = Number of samples

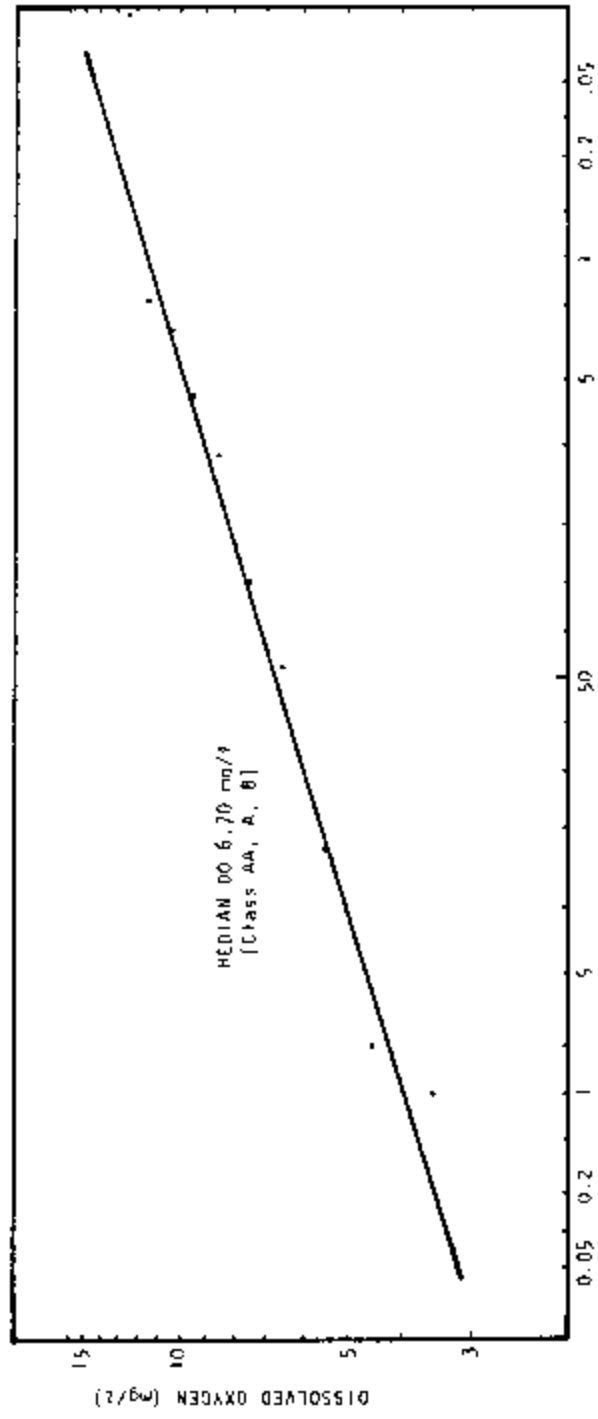

Figure 20. Probability distribution plot of dissolved oxygen for all island and class data.

the existence of potential health hazards in aqueous systems. Absolute standards have been established by the EPB (Table 3) for single samples. Arithmetic means and ranges for total and fecal coliform bacteria are presented in Tables 36 and 37. Violations of total coliform standard for class AA waters were quantified for: Majuro sites 1 and 4; Kosrae site 2. Fecal coliform standard violations for class A and B waters were identified at: Yap sites 1, 6 and 14; Moen site 8; Ponape site 7; Kosrae site 4.

Phosphorus

Arithmetic means and ranges are presented for the orthophosphate phosphorus (PO_4-P) and the total phosphorus (total P) data in Tables 38 and 39. Statistically significant differences were measured between islands (but not between classes) for the PO_4-P data. However, since all the PO_4-P means were $\leq$0.008 mgP/ℓ, a single baseline level of PO_4-P was estimated for all waters (0.005 mgP/ℓ, the mean for all data). The baseline level is less than PO_4-P literature data (0.008 mgP/ℓ: Table 4). It is noted that in subsequent limiting nutrient analyses, PO_4-P concentrations will be evaluated for each island.

Total P data were statistically different between classes. This difference was assumed to be due to the higher total P concentrations quantified in class B waters. Mean values were 0.008 mgP/ℓ (class AA and class A) and 0.013 mgP/ℓ (class B). Probability distribution plots for these two sets of classes are presented in Figures 21 (class AA, A) and 22 (class B). Median total P concentrations were estimated to be 0.007 mgP/ℓ (class AA and class A) and 0.012 mgP/ℓ (class B). Utilizing mean and median values established in this study, baseline total P concentrations were quantified as 0.008 mgP/ℓ (class AA and class A) and 0.012 mgP/ℓ (class B). These values are considerably less than the total P standards (Table 3). Literature data values were 0.018 and 0.007 mgP/ℓ (class AA: Tables 1 and 6) and 0.018 mgP/ℓ (class B: Table 1).

A single class AA sample (Yap, site 11; December 27) exceeded the TTPI standard (<0.025 mgP/ℓ). Site 11 on Yap was not in violation of the total P standard because the three day average total P concentration was 0.016 mgP/ℓ.

Nitrogen

Total nitrogen (total N) and total soluble inorganic nitrogen (TSIN) means and ranges are listed in Tables 40 and 41. Total N data did not differ significantly between islands or classes. The range of mean values for total N was 0.08 - 0.31 mgN/ℓ. The mean value for all data was 0.17 mgN/ℓ. Median total N concentration was estimated from the probability distribution plot (Figure 23) to be 0.12 mgN/ℓ. Utilizing these mean and median values, baseline total N concentration was estimated to be 0.14 mgN/ℓ for all waters.

Table 36. Arithmetic means and ranges for total coliforms (#/100 ml)

ISLAND	TTPI CLASS AA			TTPI CLASS A			TTPI CLASS B			TTPI ISLAND VALUES			
	$\bar{Y}$	(N)	Range	$\bar{Y}$	(N)	Range	$\bar{Y}$	(N)	Range	$\bar{Y}$	(N)	Range	Range of Means
MAJURO	342	(18)	0-2300	4	(3)	1-8	6	(9)	0-11	207	(30)	0-2300	4-342
EBEYE/ORGEEGUE	16	(15)	0-93	305	(3)	5-660	57	(10)	0-142	62	(28)	0-660	16-305
KOROR	1	(8)	0-4	4	(8)	0-15	19	(10)	0-51	9	(26)	0-51	1-19
YAP	28	(14)	2-87	429	(8)	0-3200	443	(9)	2-1600	252	(31)	0-3200	28-443
MOEN/DUBLON	9	(12)	0-40	16	(6)	3-52	425	(12)	1-2800	177	(30)	0-2800	9-425
PONAPE	16	(15)	0-132	23	(12)	0-122	1067	(15)	0-12,200	393	(42)	0-12,200	16-1067
KOSRAE	316	(9)	8-1200	75	(6)	4-190	334	(6)	0-1080	245	(21)	0-1200	75-334
TTPI CLASS VALUES	110	(91)	0-2300	110	(46)	0-3200	393	(71)	0-12,200	207	(208)	0-12,200	
RANGE OF MEANS	1-342			4-429			6-1067						1-1067

Underscored value represents arithmetic mean for all data.
$\bar{Y}$ = Mean
N = Number of samples

Table 37. Arithmetic means and ranges for fecal coliforms (#/100 mℓ)

ISLAND	TTPI CLASS AA			TTPI CLASS A			TTPI CLASS B			TTPI ISLAND VALUES			
	$\bar{Y}$	(N)	Range	$\bar{Y}$	(N)	Range	$\bar{Y}$	(N)	Range	$\bar{Y}$	(N)	Range	Range of Means
MAJURO	173	(18)	0-1520	2	(3)	1-4	2	(9)	0-7	105	(30)	0-1520	2-173
EBEYE/GUGEEGUE	2	(15)	0-14	8	(3)	0-18	18	(10)	0-149	8	(28)	0-149	2-18
KOROR	< 1	(8)	0-1	1	(8)	0-4	4	(10)	0-36	2	(26)	0-36	< 1-4
YAP	41	(16)	0-397	117	(9)	0-810	2241	(11)	4-12,700	732	(36)	0-12,700	41-2241
MOEN/DUBLON	3	(12)	0-22	5	(6)	2-12	309	(12)	0-2400	126	(30)	0-2400	3-309
PONAPE	10	(15)	0-75	18	(12)	0-156	661	(15)	0-6000	245	(42)	0-6000	10-661
KOSRAE	184	(9)	0-1030	5	(6)	0-21	143	(6)	0-600	121	(21)	0-1030	5-184
TTPI CLASS VALUES	61	(93)	0-1520	72	(47)	0-810	547	(72)	0-12,700	<u>227</u>	(213)	0-12,700	
RANGE OF MEANS	< 1-184			1-117			2-2241						< 1-2241

Underscored value represents arithmetic mean for all data.
$\bar{Y}$ = Mean
N = Number of samples

Table 38. Arithmetic means and ranges for orthophosphate phosphorus (mg PO_4-P/ℓ)

ISLAND	TTPI CLASS AA			TTPI CLASS A			TTPI CLASS B			TTPI ISLAND VALUES			
	$\bar{Y}$	(N)	Range	$\bar{Y}$	(N)	Range	$\bar{Y}$	(N)	Range	$\bar{Y}$	(N)	Range	Range of Means
MAJURO	.005	(19)	.003-.007	.004	(3)	.004	.006	(9)	.003	.005	(30)	.003-.014	.004-.006
EBEYE/GUGEEGUE	.008	(15)	.006-.010	.006	(3)	.004-.007	.007	(9)	.003-.009	.007	(27)	.003-.010	.006-.008
KOROR	.005	(11)	.001-.011	.005	(9)	.002-.010	.008	(14)	.001-.036	.006	(34)	.001-.036	.005-.008
YAP	.001	(16)	.000-.006	.007	(9)	.000-.006	.001	(12)	.000-.006	.001	(37)	.000-.006	.001-.002
NOEN/DUBLON	.005	(12)	.000-.007	.005	(6)	.004-.007	.006	(12)	.000-.020	.005	(30)	.000-.020	.005-.006
PONAPE	.005	(15)	.003-.008	.007	(12)	.004-.010	.007	(15)	.003-.023	.006	(42)	.003-.023	.005-.007
KOSRAE	.005	(9)	.002-.007	.006	(6)	.002-.011	.008	(5)	.003-.013	.006	(20)	.002-.013	.005-.008
TTPI CLASS VALUES	.005	(96)	.000-.011	.005	(48)	.000-.011	.006	(76)	.000-.036	<u>.005</u>	(220)	.000-.036	
RANGE OF MEANS	.001-.008			.002-.007			.001-.008						.001-.008

Underscored value represents arithmetic mean for all data.

$\bar{Y}$ = Mean

N = Number of samples

Table 39. Arithmetic means and ranges for total phosphorus (mg P/ℓ)

ISLAND	TTPI CLASS AA			TTPI CLASS A			TTPI CLASS B			TTPI ISLAND VALUES			
	$\bar{Y}$	(N)	Range	$\bar{Y}$	(N)	Range	$\bar{Y}$	(N)	Range	$\bar{Y}$	(N)	Range	Range of Means
MAJURO	.007	(18)	.004-.015	.008	(3)	.007-.008	.009	(9)	.006-.014	.008	(30)	.004-.015	.007-.009
EBEYE/GUGEEGUE	.008	(15)	.006-.012	.010	(3)	.008-.014	.010	(9)	.008-.014	.009	(27)	.006-.014	.008-.010
KOROR	.009	(9)	.004-.023	.008	(11)	.004-.013	.013	(14)	.006-.079	.010	(34)	.004-.079	.008-.013
YAP	.010	(16)	.006-.030	.010	(9)	.008-.011	.013	(12)	.008-.026	.011	(37)	.006-.030	.010-.013
MOEN/DUBLON	.008	(11)	.003-.011	.008	(6)	.004-.014	.017	(11)	.003-.092	.012	(28)	.003-.092	.008-.017
PONAPE	.006	(10)	.003-.013	.007	(10)	.006-.010	.013	(10)	.005-.024	.009	(30)	.003-.024	.006-.013
KOSRAE	.010	(9)	.006-.015	.008	(6)	.004-.012	.020	(6)	.007-.045	.012	(21)	.004-.045	.008-.020
TTPI CLASS VALUES	.008	(88)	.003-.030	.008	(48)	.004-.014	.013	(71)	.003-.092	<u>.010</u>	(207)	.003-.092	
RANGE OF MEANS	.006-.010			.007-.010			.009-.020						.006-.020

Underscored value represents arithmetic mean for all data.

$\bar{Y}$ = Mean

N = Number of samples

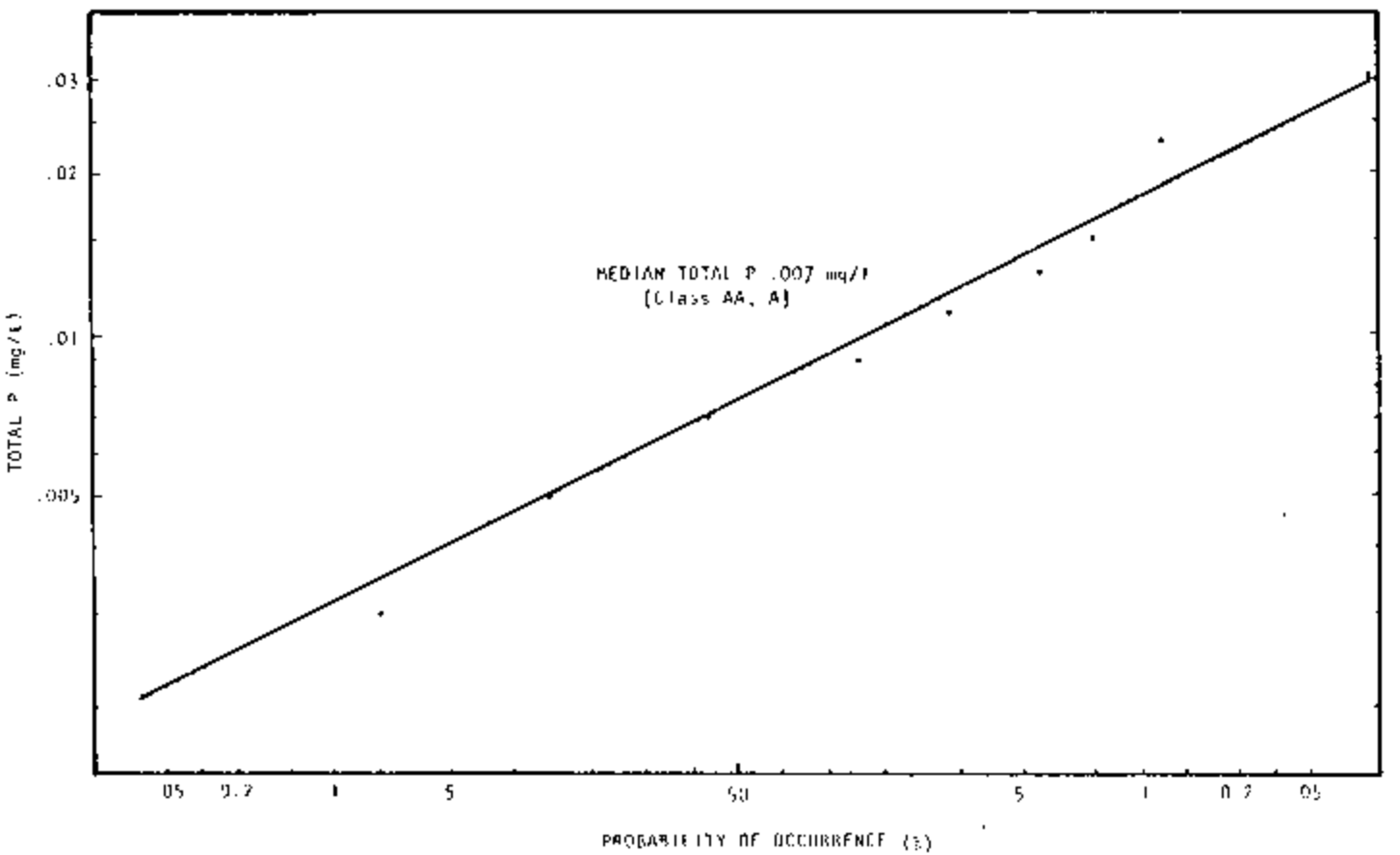

Figure 21. Probability distribution plot of total phosphorus for all AA and A waters.

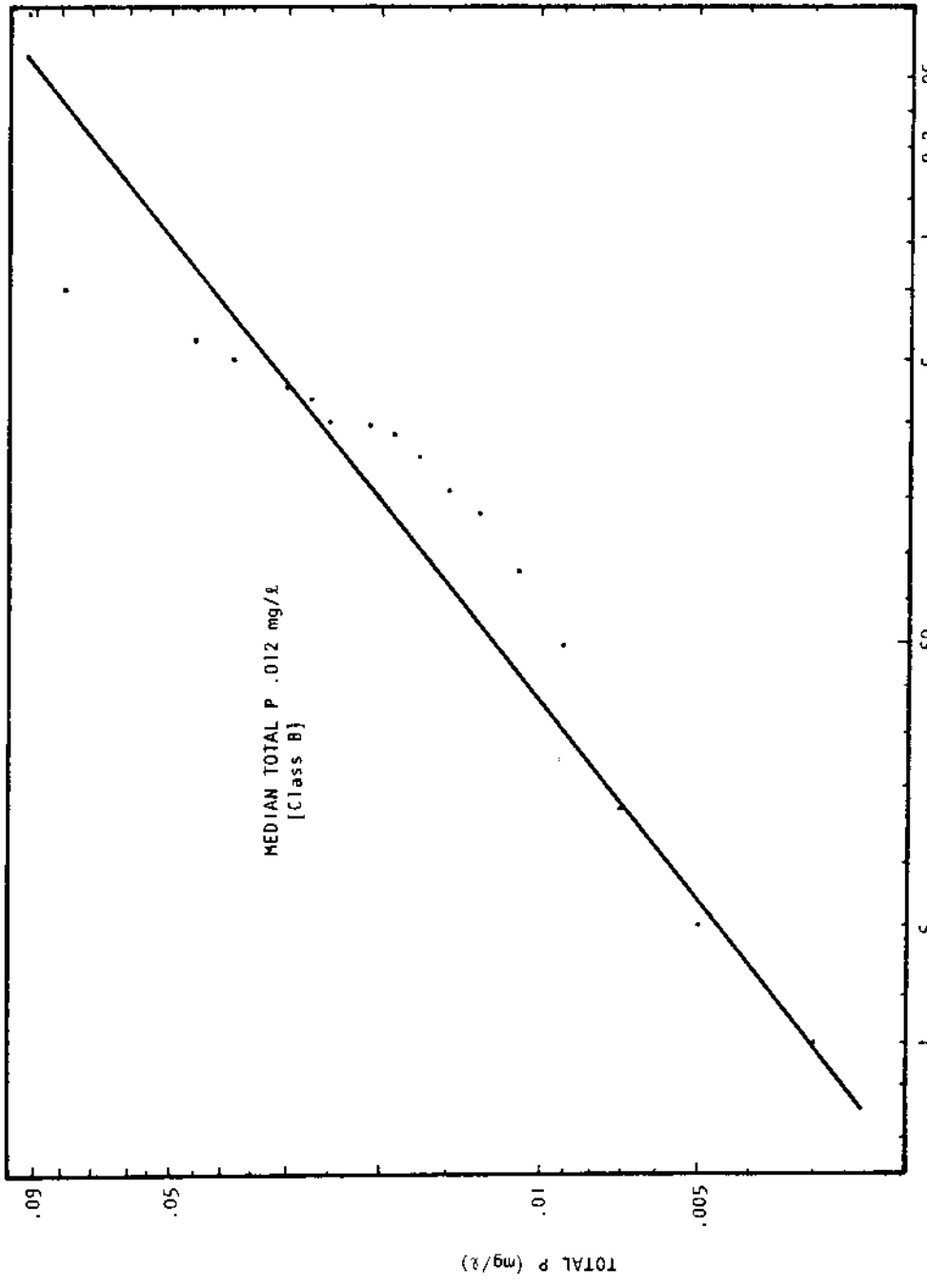

Figure 22. Probability distribution plot of total phosphorus for all class B waters.

Table 40. Arithmetic means and ranges for total nitrogen (mg N/ℓ).

ISLAND	TTPI CLASS AA			TTPI CLASS A			TTPI CLASS B			TTPI ISLAND VALUES			
	$\bar{Y}$	(N)	Range	$\bar{Y}$	(N)	Range	$\bar{Y}$	(N)	Range	$\bar{Y}$	(N)	Range	Range of Means
MAJURO	.12	(16)	.01-.24	.13	(3)	.05-.24	.11	(9)	.01-.51	.12	(28)	.01-.51	.11-.13
EBEYE/GUGEEGUE	.23	(13)	.03-.46	.31	(3)	.22-.36	.16	(8)	.02-.50	.21	(24)	.02-.50	.16-.31
KOROR	.28	(12)	.02-.54	.18	(12)	.01-.35	.23	(15)	.08-.44	.23	(39)	.01-.54	.18-.28
YAP	.15	(16)	.06-.34	.19	(8)	.13-.34	.16	(12)	.05-.44	.16	(36)	.05-.44	.15-.19
MOEN/DUBLON	.08	(9)	.01-.14	.09	(4)	.05-.13	.26	(8)	.01-.77	.15	(20)	.01-.77	.08-.26
PONAPE	.12	(10)	.04-.28	.09	(9)	.01-.19	.16	(10)	.09-.50	.12	(29)	.01-.50	.09-.16
KOSRAE	.17	(9)	.09-.22	.19	(6)	.11-.31	.22	(6)	.09-.42	.19	(21)	.09-.42	.17-.22
TTPI CLASS VALUES	.17	(84)	.01-.54	.16	(45)	.01-.36	.19	(68)	.01-.77	<u>.17</u>	(197)	.01-.77	
RANGE OF MEANS	.08-.28			.09-.31			.11-.26						.08-.31

Underscored value represents arithmetic mean for all data.
$\bar{Y}$ = Mean
N = Number of samples

Table 41. Arithmetic means and ranges for total soluble inorganic nitrogen (mg TSIN/ℓ)

ISLAND	TTPI CLASS AA			TTPI CLASS A			TTPI CLASS B			TTPI ISLAND VALUES			
	$\bar{Y}$	(N)	Range	$\bar{Y}$	(N)	Range	$\bar{Y}$	(N)	Range	$\bar{Y}$	(N)	Range	Range of Means
MAJURO	.027	(18)	.005-.073	.025	(3)	.014-.046	.027	(9)	.005-.048	.027	(30)	.005-.073	.025-.027
EBEYE/GUGEEGUE	.021	(14)	.008-.054	.019	(3)	.012-.032	.024	(9)	.014-.035	.022	(26)	.008-.054	.019-.024
KOROR	.041	(11)	.027-.079	.030	(9)	.006-.054	.039	(13)	.019-.080	.037	(33)	.006-.080	.030-.041
YAP	.033	(15)	.021-.053	.037	(9)	.022-.080	.046	(11)	.021-.110	.038	(35)	.021-.110	.033-.046
MOEN/DUBLON	.056	(8)	.015-.096	.086	(4)	.045-.166	.066	(8)	.034-.082	.066	(20)	.015-.166	.056-.086
PONAPE	.060	(14)	.029-.081	.066	(11)	.025-.105	.073	(15)	.043-.110	.066	(40)	.025-.110	.060-.073
KOSRAE	.050	(9)	.023-.103	.064	(6)	.038-.092	.061	(6)	.040-.079	.057	(21)	.023-.103	.050-.064
TTPI CLASS VALUES	.039	(89)	.005-.103	.049	(45)	.006-.166	.049	(71)	.005-.110	<u>.045</u>	(205)	.005-.166	
RANGE OF MEANS	.021-.060			.019-.086			.024-.073						.019-.086

Underscored value represents arithmetic mean for all data.
$\bar{Y}$ = Mean
N = Number of samples

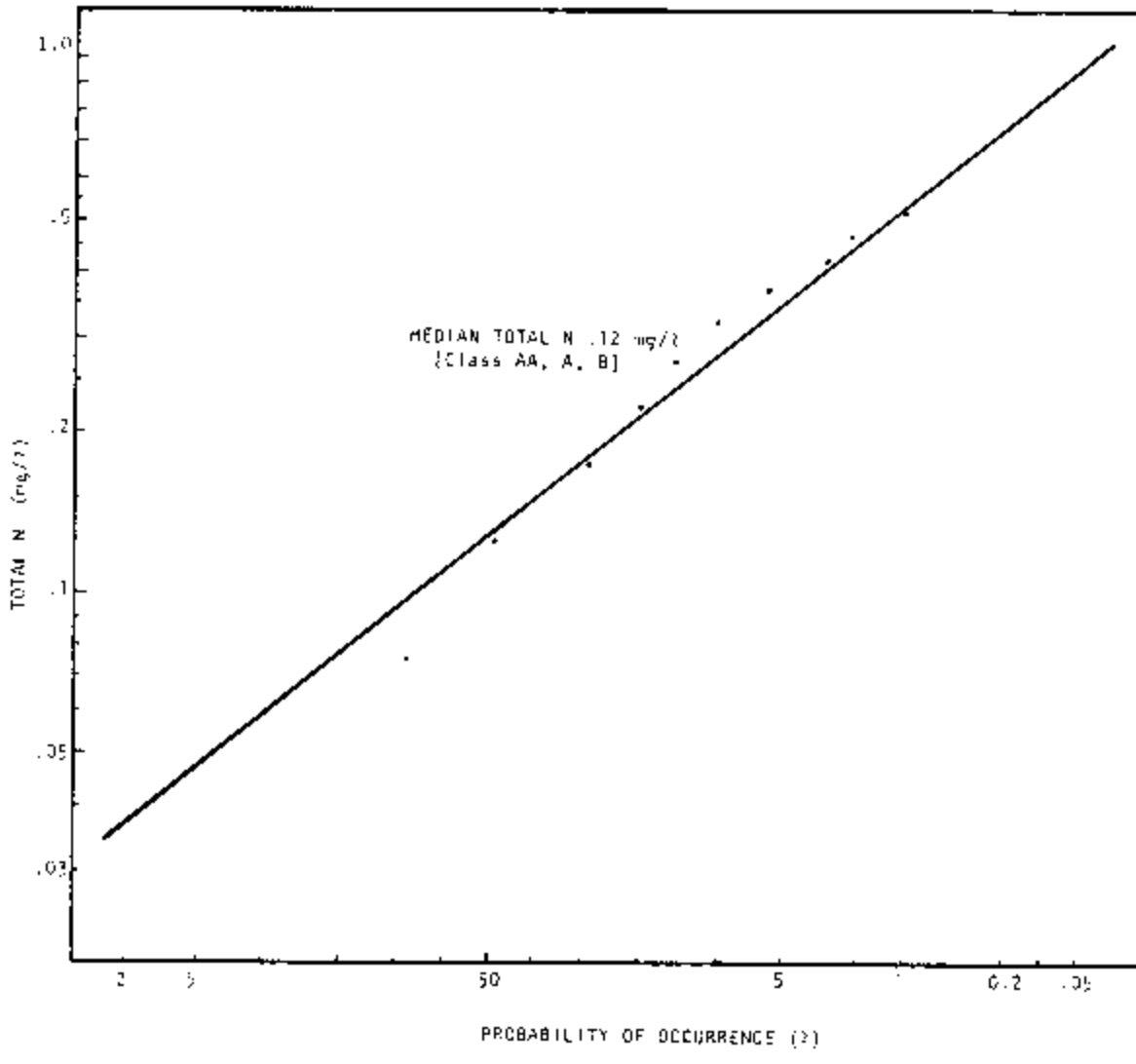

Figure 23. Probability distribution plot of total nitrogen for all island and class data.

Background levels of total N, which are in agreement with literature data (0.16 mgN/ℓ, Table 4), are considerably less than the TTPI standards for total N (Table 3). Class AA sites 4 (Ebeye/Gugeegue, November 29) and 1 (Koror, December 20) had total N concentrations >0.40 mgN/ℓ. However, these sites were not in violation of the total N standard because average total N concentrations were 0.24 and 0.36 mgN/ℓ, respectively.

The mean concentrations of TSIN (Table 41) differed significantly between islands; the range of mean values was 0.019 - 0.086 mgN/ℓ. Baseline TSIN concentrations were: 0.025 mgN/ℓ (Majuro, Ebeye, Gugeegue); 0.038 mgN/ℓ (Koror, Yap); 0.64 mgN/ℓ (Moen, Dublon, Ponape, Kosrae). The mean TSIN concentration for all waters was estimated at 0.045 mgN/ℓ.

Total Nitrogen/Total Phosphorus

Two-way analysis of variance of the mean total nitrogen data showed no statistically significant differences between islands or between classes. The variance for all data was not different from the variances of the data grouped by islands or classes. Territorial total N concentration was estimated to be 0.14 mgN/ℓ. Statistically significant differences between the variance of all data and the variance of the data grouped by classes was identified for total phosphorus. Class AA and class A total P concentrations were estimated to be 0.008 mgP/ℓ; class B total P concentration was 0.012 mgP/ℓ. Total N/Total P mass ratios based upon these estimates are:

Class AA, Class A	(0.14 mgN/ℓ)/(0.008 mgP/ℓ) =	18/1
Class B	(0.14 mgN/ℓ)/(0.012 mgP/ℓ) =	12/1

Utilizing the mean total N (Table 40) and total P (Table 39) data, the range of mass ratios for class AA and A waters was 10/1 to 27/1. The range of class B waters was 11/1 to 18/1. These mass ratios for total N and total P are not the same as the mass ratios of inorganic nitrogen and phosphorus.

Proposed Marine Water Quality Amendments

Results from the baseline study quantify water quality conditions for near shore marine waters in the TTPI. Proposed amendments to the marine water quality standards relevant to the assessed territorial waters are summarized in Table 42. Existing pH values for surface waters are in the upper portion of the range established in the existing marine water quality standard (Table 3). Since 98% of all observed pH values were between 7.70 and 8.50, the standard should be established as 8.10 ± 0.4 pH units. Utilizing mean values measured at each site studied, there were no violations of the amended standard.

Table 42. Proposed amendments to Trust Territory of the Pacific Islands (TTPI) marine water quality standards.*

PARAMETER	UNITS	CLASS AA	CLASS A	CLASS B
pH		----------[6.5≤pH≤8.5]----------		
		----------[8.10±0.40]----------		
Total Nitrogen	mg/ℓ	≤0.40	≤0.40	≤0.80
Total Phosphorus	mg/ℓ	≤0.025	≤0.025	≤0.050
TN/TP (mass ratio)		9≤18≤27	9≤18≤27	6≤12≤18
Salinity	o/oo	----------[32±3]----------		
Temperature	°C	----------[29.0±1.5]----------		
Turbidity	NTU	≤1.0	≤1.0	≤2.0

*These proposed amendments apply to TTPI marine waters in general. If isolated areas in the Territory have water quality parameter values in violation of these proposed standards, sufficient data should then be gathered in order to establish the normal conditions for these special cases.

Total nitrogen and total phosphorus standards (Table 3) were concluded to be too high for class A and class B waters. Amended values for these classes should be 0.40 mgN/ℓ (class A) and 0.80 mgN/ℓ (class B) for total nitrogen and 0.025 mgP/ℓ (class A) and 0.050 mgP/ℓ (class B) for total phosphorus. Utilizing mean values measured at each site studied, there were no violations of these amended standards.

Total nitrogen/total phosphorus (TN/TP) mass ratios were established as 18/1 and 12/1 for class AA, A and class B waters, respectively. Lower mass ratios in class B waters were attributed to the higher total P concentrations in these waters as compared to class AA and A waters. The TN/TP mass ratio at the amended nitrogen and phosphorus standard levels (Table 42) for all waters was 16/1. The ranges of ratios were 18 ± 9 and 12 ± 6 for class AA, A and class B waters. In terms of percent change, it is noted that the range for all classes was the estimated baseline ratio ± 50%.

The baseline condition for salinity was estimated as 32 °/oo. Existing salinity standard (Table 3) is baseline salinity ± 10%; this range adequately quantifies this water quality parameter. The standard listed in Table 42 is 32 ± 3 °/oo for all water classifications, where 3 °/oo represents 10 percent of 32 °/oo rounded to the nearest part per thousand (°/oo).

Water temperature, which is a function of ambient air temperature, rainfall, depth of site and mixing regimes, was concluded to be invariant between islands and water classes. Since 90% of all observed water temperatures (Figure 16) and 100% of all arithmetic mean water temperatures (Table 31) quantified in this study were within the range of 27.5 - 30.5°C, the water quality standard for all classes was established as 29.0 ± 1.5°C. Majuro class AA site 9 (Table 10) and Kosrae class AA site 2 (Table 29) had water temperatures above (site 9) and below (site 2) the standard temperature range. The measured temperatures were 29.0, 33.6 and 33.6°C for Majuro site 9 with corresponding site depths of 1.7, 0.7 and 0.5 m. The high water temperatures on November 22 and 23 were due to decreased site depth on those days. The cause of the low water temperatures for Kosrae site 2 (average: 26.7°C) was not ascertained.

Estimates of baseline turbidity for class AA, A and class B waters were 0.6 and 0.8 NTU, respectively. Since the observed turbidities from both sets of classes were skewed to the right, upper limits were established based upon the distributions of the data. The probability distribution plots (Figures 18 and 19) show that 80% of all measured turbidities were $\leq$1.0 NTU (class AA, A) and $\leq$2.0 NTU (class B). The proposed water quality standards for turbidity were set at these limits.

Since only three measurements were made at each site in this study, indicated violations of turbidity standards are only estimates:

Koror class A site 6 (average: 1.4 NTU; Table 17); Yap class AA sites 11, 12 and class B site 14 (December 27 data: 2.1, 1.2 and 4.7 NTU; Table 20); Moen class AA site 5 and class B site 8 (January 4 data: 1.6 and 4.5 NTU; Table 23); Ponape class A site 9 and class B site 7 (January 8, 9 data averages: 1.2 and 2.7 NTU; Table 26). In order to confirm these estimated violations of turbidity standards, more data must be obtained at these sites. Establishment of an adequate data base could confirm the existence of higher baseline turbidity values at these sites.

Limiting Nutrients

Marine waters surrounding the islands of Majuro, Ebeye, Gugeegue, Koror, Yap, Moen, Dublon, Ponape and Kosrae are of high clarity and have low inorganic N and P nutrient concentrations. Inorganic nitrogen and phosphorus ratios are used to analyze the extent of water pollution in terms of phytoplankton primary productivity. Specific sites of high primary productivity are estimated to be: Chamorro Bay in the Colonia area of Yap; harbor area off Mwalok near the sewer outfall, Ponape; Temwen side of Metalanim Harbor, Ponape. Excluding these three areas, the territorial waters have low potentials for phytoplankton blooms if existing baseline conditons of water quality are maintained. In order to quantify these low potentials, phytoplankton growth rate limiting nutrient(s) were estimated.

The concentrations of total soluble inorganic nitrogen (TSIN) and orthophosphate phosphorus (PO_4-P) for the islands studied are listed in Table 43. Mass ratios were calculated and it was assumed that waters having (TSIN)/(PO_4-P) ratios <15/1 were nitrogen limited; ratios in excess of 15/1 were assumed to be phosphorus limited. All waters studied except those surrounding Yap were concluded to be nitrogen limited (Figure 24). Phosphorus limitation of the Yap waters was concluded to be due to extremely low (28 of 36 samples $\leq$0.001 mgP/ℓ) PO_4-P concentrations.

Biomass yields were calculated according to literature yield data using the green test alga, *Dunaliella tertiolecta* (U.S.E.P.A., 1974): 1.08 mg dry weight/μg PO_4-P; 0.03 mg dry weight/μg NO_3-N; 0.08 mg dry weight/μg NH_3-N; where microgram (μg) = 0.001 mg. Yield data for territorial waters are listed in Table 44. The underscored values in Table 44 represent the smallest yield possible between PO_4-P and TSIN nutrients. Based on yield data, all samples except Yap waters were nitrogen limited. It is noted that yields from inorganic nitrogen are assessed in terms of NO_3-N and NH_3-N; whereas TSIN represents these parameters plus nitrite nitrogen (NO_2-N). It is assumed that NO_2-N concentrations were <0.001 mgN/ℓ; therefore, yield data from inorganic nitrogen [(NO_3+NH_3)-N] correspond to yield data quantified as TSIN: $[(NO_3 + NO_2 + NH_3)\text{-}N]$.

Table 43. Trust Territory of the Pacific Island limiting nutrient data.

ISLAND	TSIN* mg N/ℓ	PO_4-P** mg P/ℓ	[TSIN/(PO_4-P] mass ratio	LIMITING NUTRIENT
MAJURO	.027	.005	5.4/1	N
EBEYE/GUGEEGUE	.022	.007	3.1/1	N
KOROR	.037	.006	6.2/1	N
YAP	.038	.001	38/1	P
MOEN/DUBLON	.066	.005	13/1	N
PONAPE	.066	.006	11/1	N
KOSRAE	.057	.006	9.5/1	N
TTPI	.045	.005	9.0/1	N

* Total Soluble Inorganic Nitrogen
** Orthophosphate Phosphorus

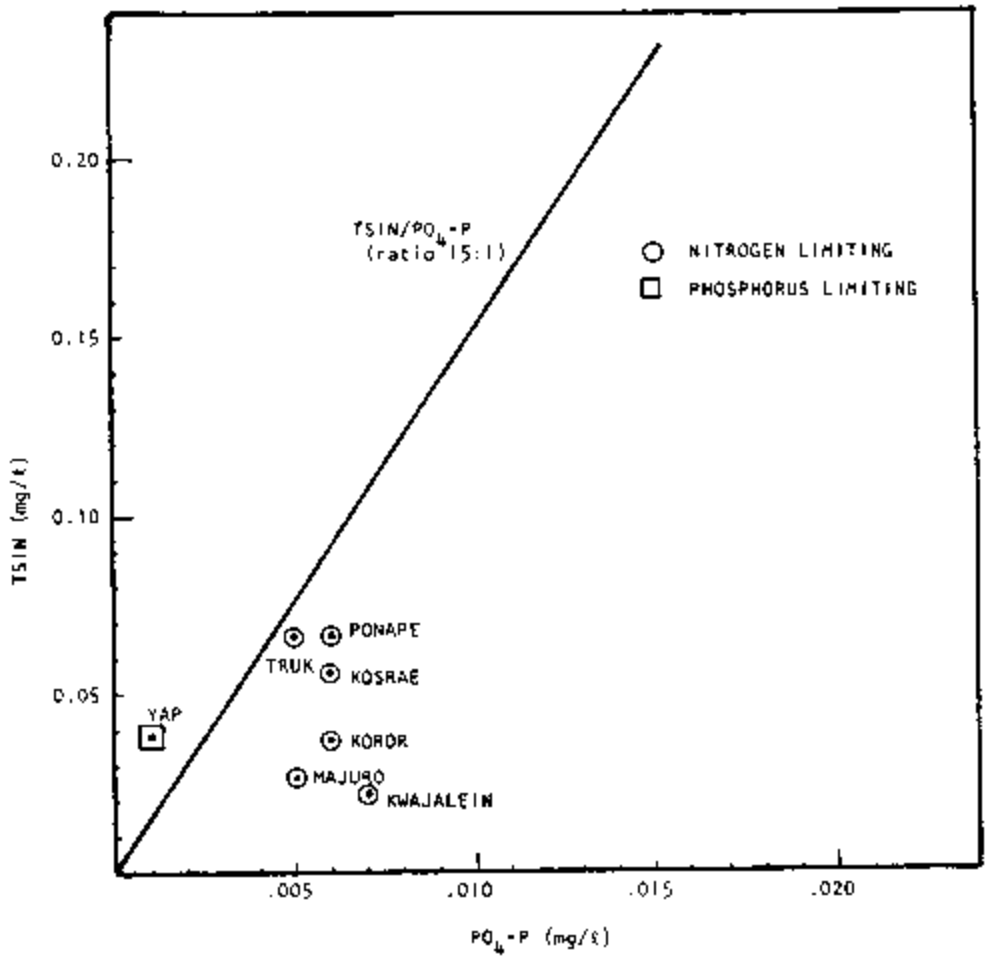

Figure 24. Total soluble inorganic nitrogen versus orthophosphate-phosporus. See Table 43.

Table 44. Trust Territory of the Pacific Islands biomass yield data.

ISLAND	BIOMASS YIELDS (mg dry weight) $[PO_4\text{-}P]$	$[(NO_3+NO_2)\text{-}N]$	+ $[NH_3\text{-}N]$	= [TSIN]	LIMITING NUTRIENT
MAJURO	5.40	0.36	1.20	1.56	N
EBEYE/GUGEEGUE	7.56	0.27	0.96	1.23	N
KOROR	6.48	0.42	1.84	2.26	N
YAP	1.08	0.33	2.16	2.49	P
MOEN/DUBLON	5.40	0.57	3.76	4.33	N
PONAPE	6.48	0.36	4.32	4.68	N
KOSRAE	6.48	0.27	3.84	5.11	N
TTPI	5.40	0.33	2.72	3.05	N

Underscored values represent limited nutrient yields.

Recommendations for Future Research

High clarity and low concentrations of inorganic nitrogen and phosphorus nutrients characterize the waters of the TTPI. However, isolated areas around the district centers of Micronesia warrant further study. It is recommended that district sanitarians should evaluate the marine waters in the following areas:

1. Majuro sites 1 (Darrit) and 4 (Uliga), ocean areas of high coliform concentrations.

2. Yap site 14 (Chamorro Bay), area of extremely high coliform concentrations, phytoplankton populations and turbidities; sites 1 (Worworo) and 6 (Gilfiz), areas of high coliform concentrations.

3. Moen site 8 (Peniesene, bay), a recreation area, high coliform concentrations and turbidities; site 5 (Epinup), turbidity violations.

4. Ponape site 7 (Kolonia), coliform and turbidity violations; site 9 (Mandolmal), high turbidity.

5. Kosrae site 2 (Tafonsak), a recreation area, low dissolved oxygen concentrations and high coliform concentrations and turbidities; site 4 (Lele Harbor), coliform violations; site 1 (Okat), low dissolved oxygen concentrations.

Monitoring programs must be established on the local level in order to evaluate these isolated areas and to adequately assess environmental impacts of future development on the marine waters surrounding the district centers in Micronesia. Monitoring programs, in addition to developing a more complete data base, would allow evaluation of water pollution control problems. For example, diurnal studies could be performed on Kosrae sites 1 and 2 to determine if D.O. levels are in violation of standards or if the low values measured in this study were solely due to the early morning sampling times (classically periods of low D.O.). Expanded monitoring programs would allow evaluation of benthic as well as planktonic communities in order to more compresensively analyzed nutrient limitation concepts.

Standardized laboratory equipment and analytical procedures should be designated for all district sanitation offices. Local laboratory technicians should be trained in sampling methodologies (site location, sampling frequency, sampling techniques), and laboratory procedures (analytical techniques, data handling, data reporting). It is therefore recommended that training programs be established and/or expanded by the EPB such that district sanitarians and technicians acquire expertise in environmental water quality.

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