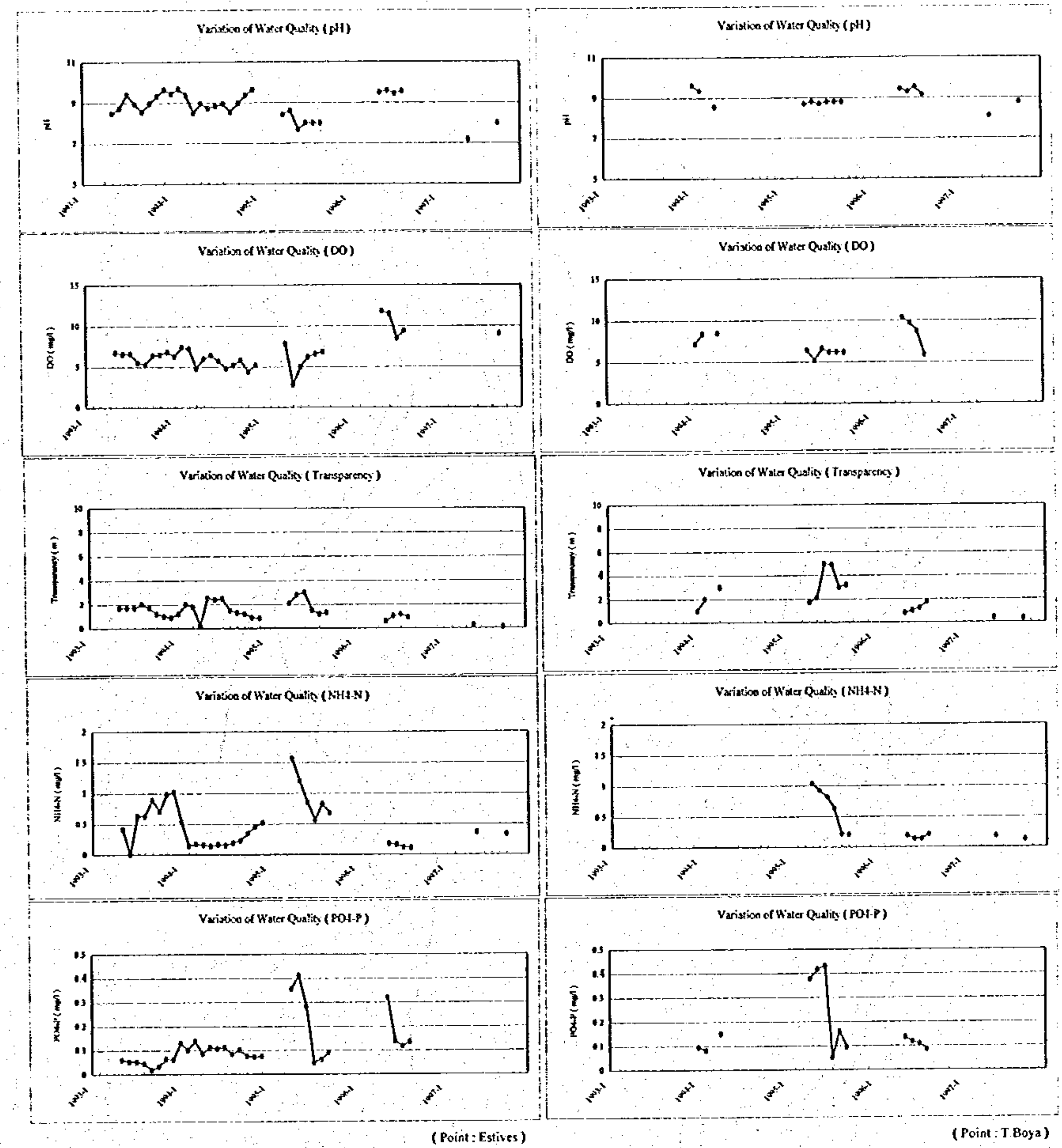


Figure III.3.1 The Transition of the Water Quality in Puno Interior Bay (1992 - 1996)

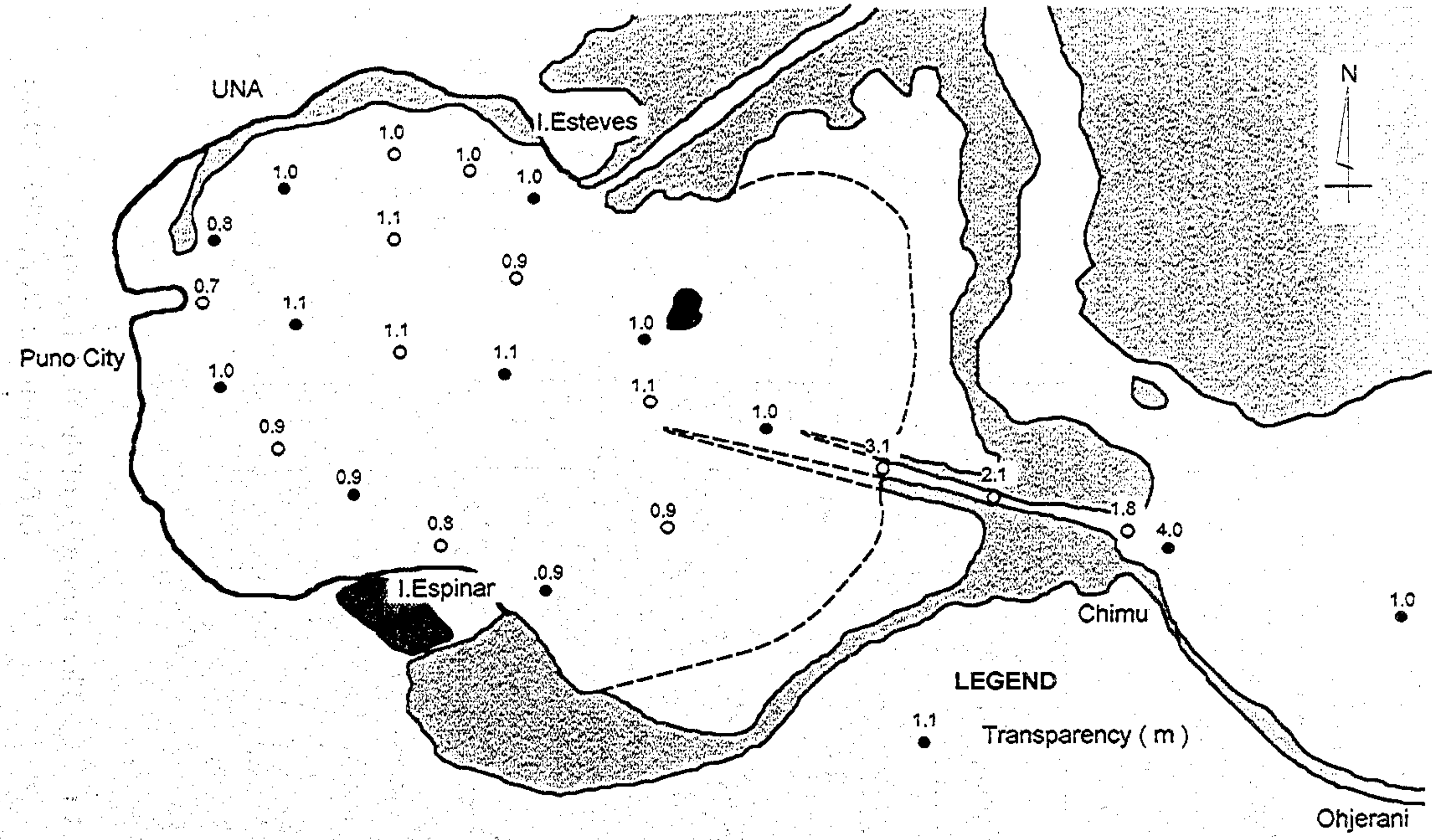
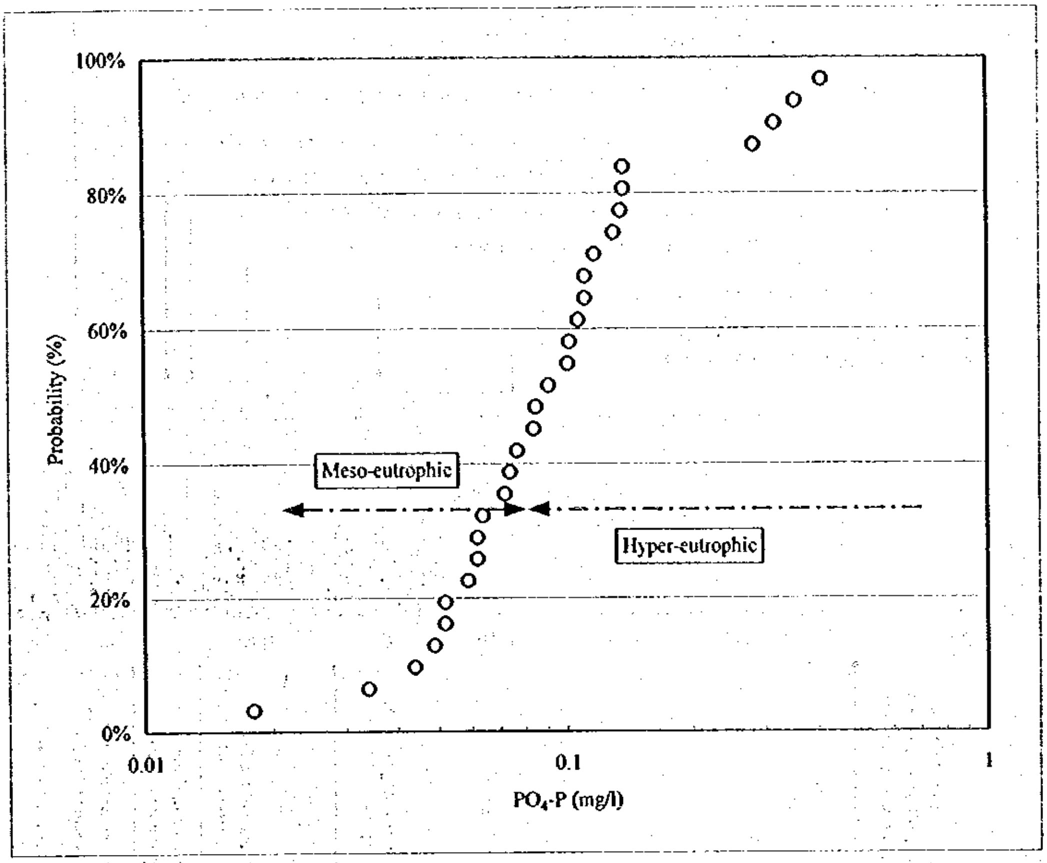


Figure III.3.2 The Regional Variation of Water Quality (12 Jun 1996)



source : PELT(1993 - 1997)

Meso-eutrophic	0.03 - 0.1 mg/l as Total - P
Hyper-eutrophic	>0.1 mg/l as Total - P

Assuming that PO_4-P concentration account for 80 % of Total - Pin Lake.

Meso-eutrophic	0.024 - 0.08 mg/l as PO_4 - P
Hyper-eutrophic	>0.08 mg/l as PO_4- P

Figure III.3.3 The Level of Eutrophication in Puno Interior Bay (1992 - 1996)

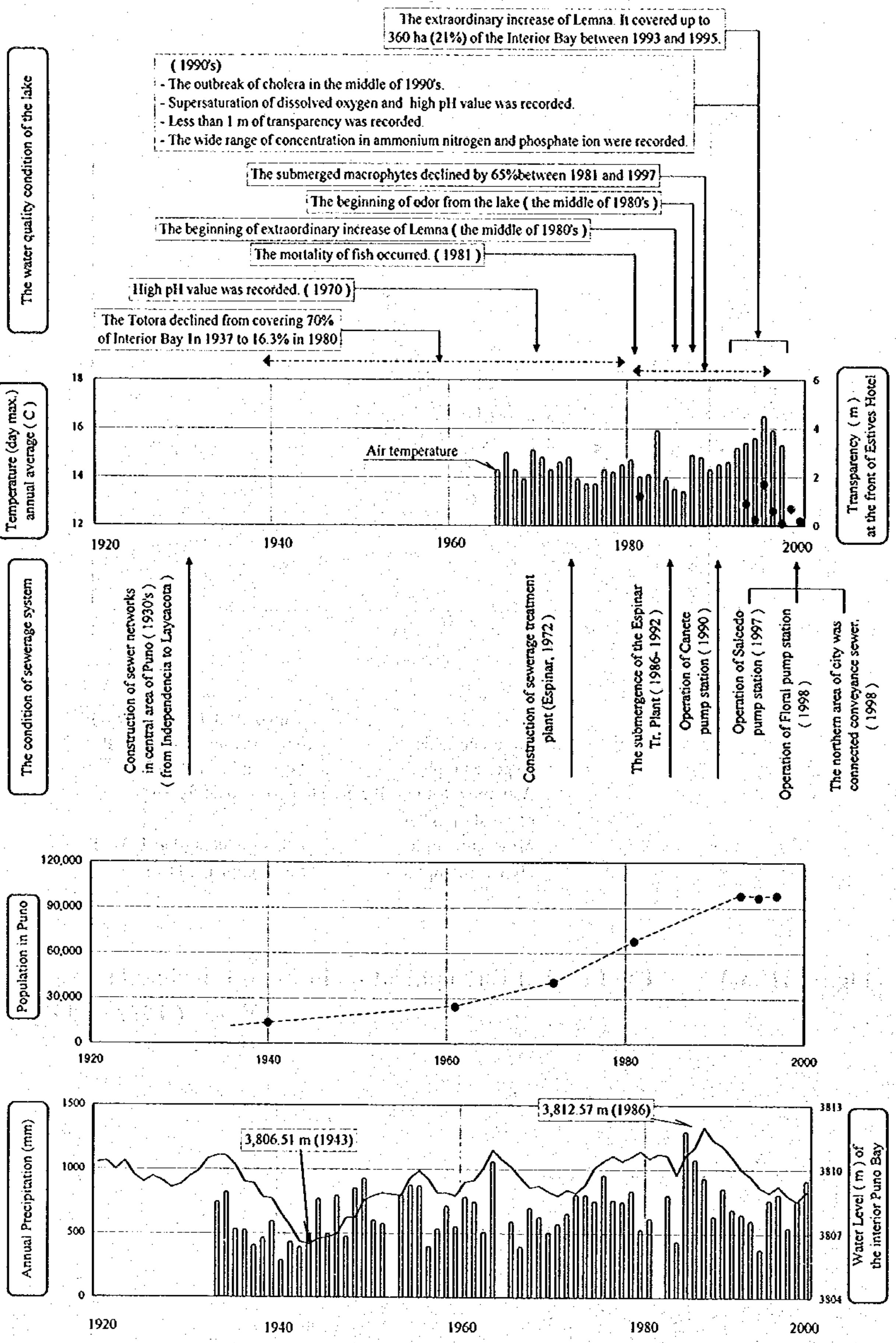
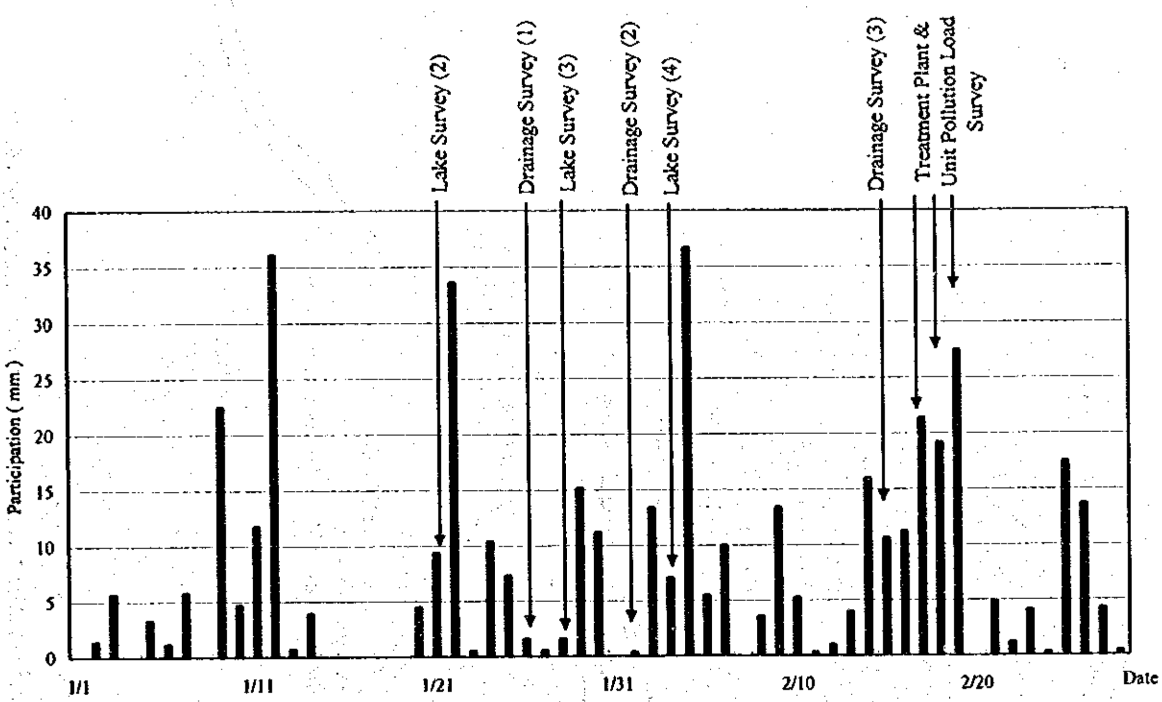


Figure III.3.4 The Transition of Puno Interior Bay and Its Background



Source : SENAM

Figure III.3.5 The Date of Field Survey and Its Weather Condition (Rainy Season)

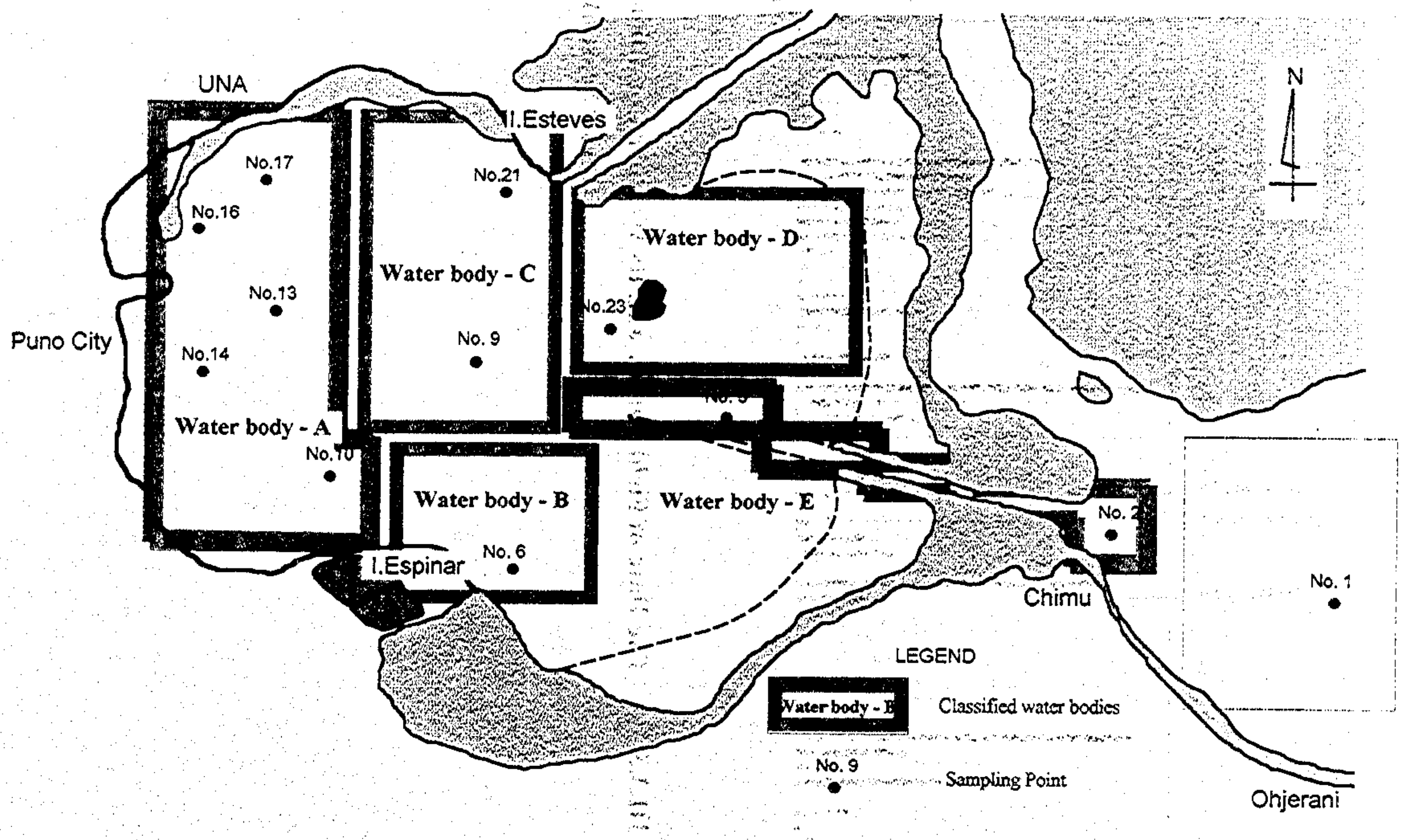


Figure III.3.6 Sampling Points of Field Survey (Lake Water and Sediment) and the Classified Water Bodies in Puno Interior Bay

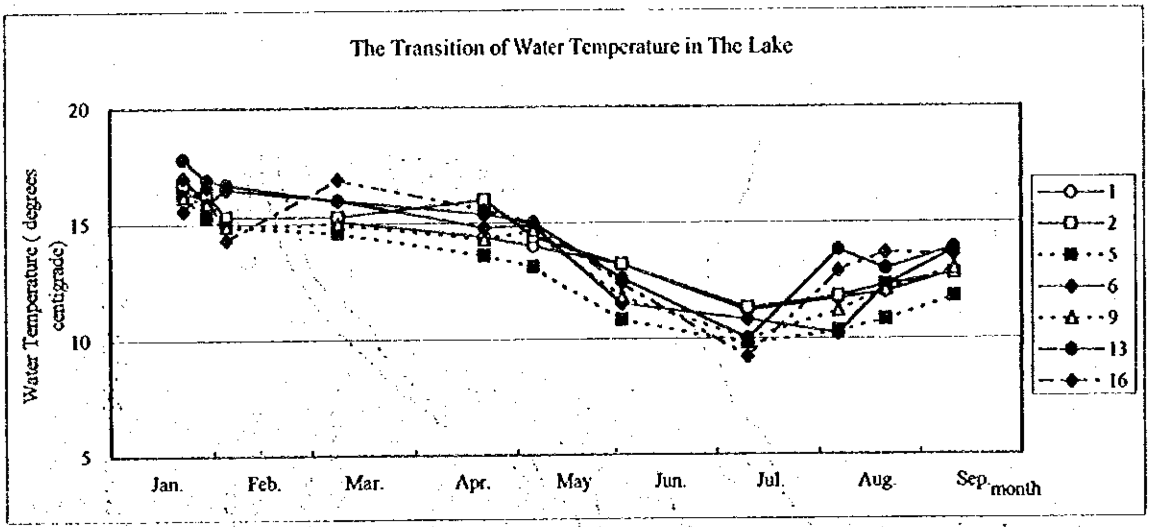


Figure III.3.7 The Transition of Water Temperature in Puno Interior Bay

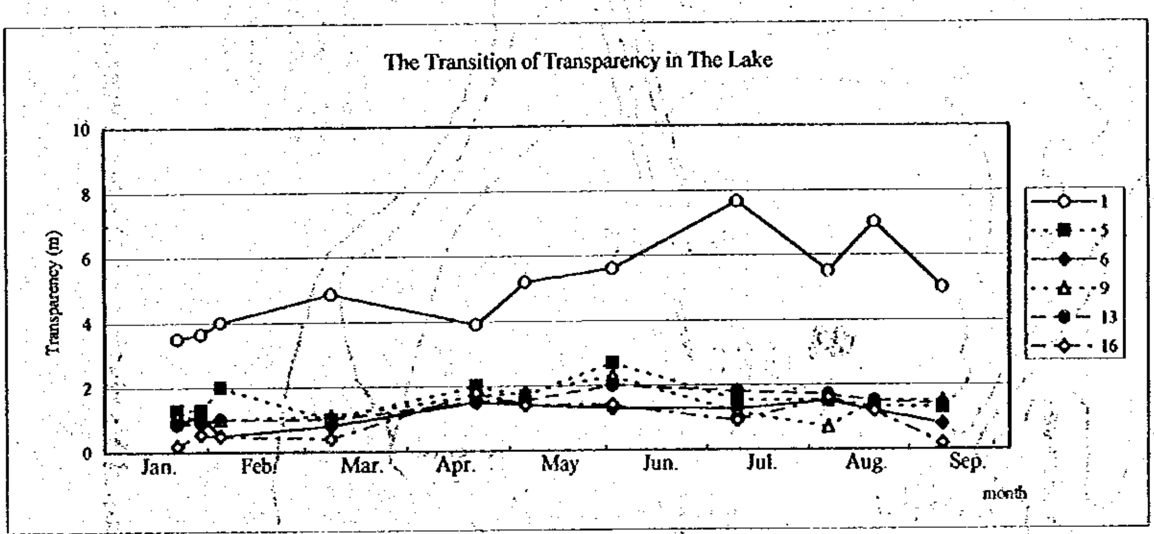


Figure III.3.9 The Transition of Transparency in Puno Interior Bay

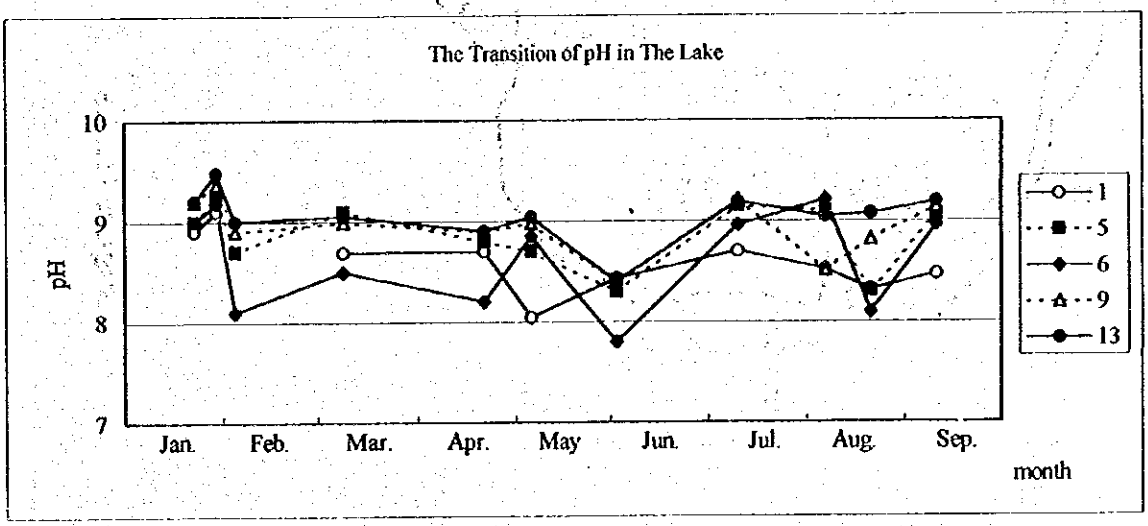


Figure III.3.10 The Transition of pH in Puno Interior Bay

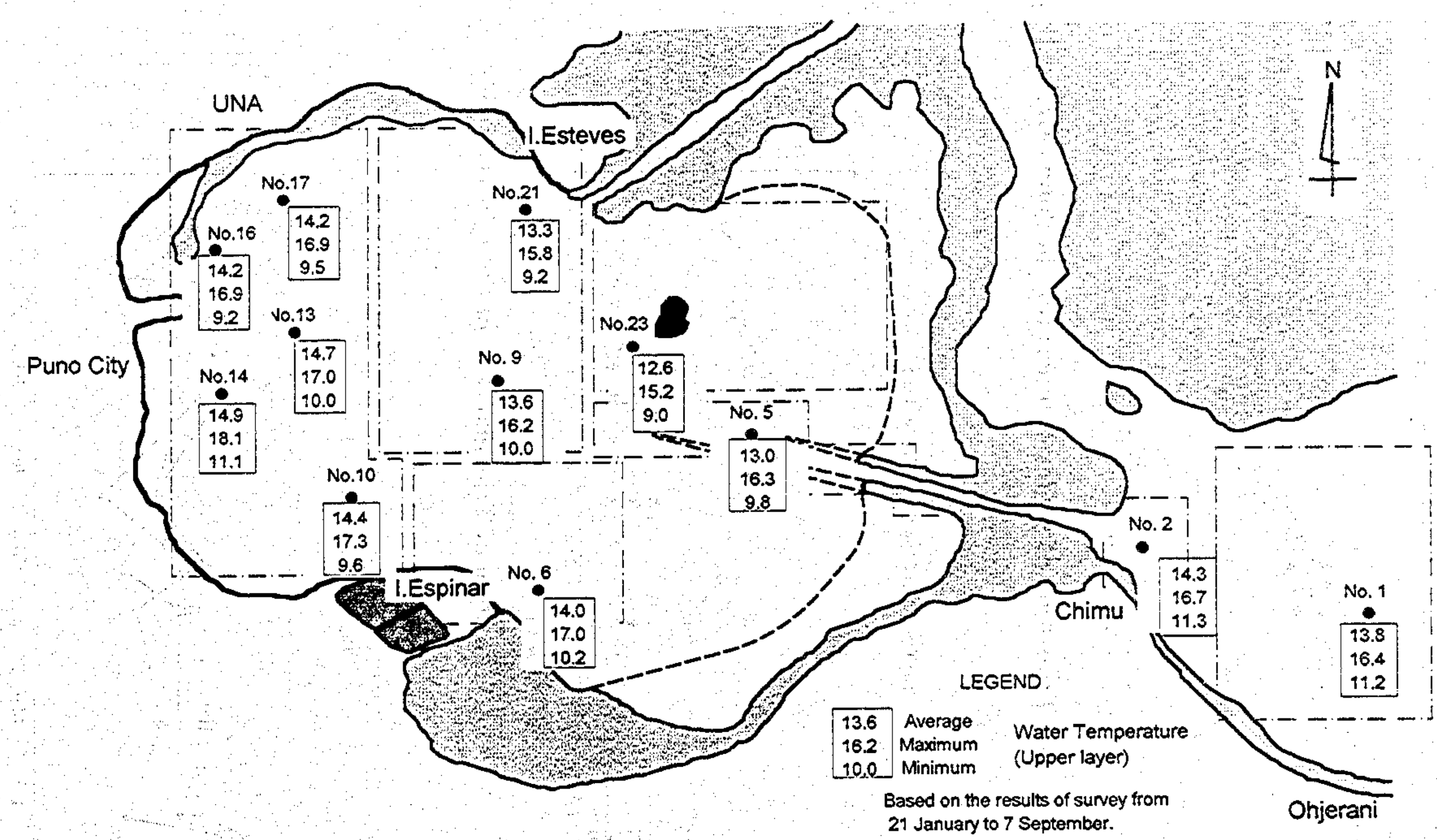


Figure III.3.8 **The Regional Variation of Water Temperature in Puno Interior Bay**

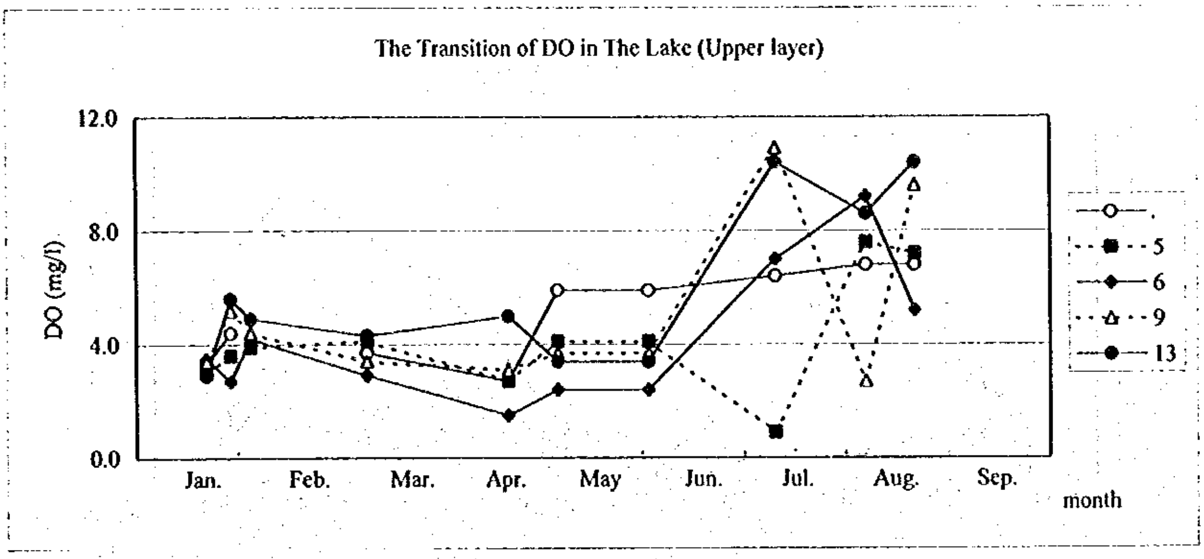


Figure III.3.11 The Transition of DO in Puno Interior Bay

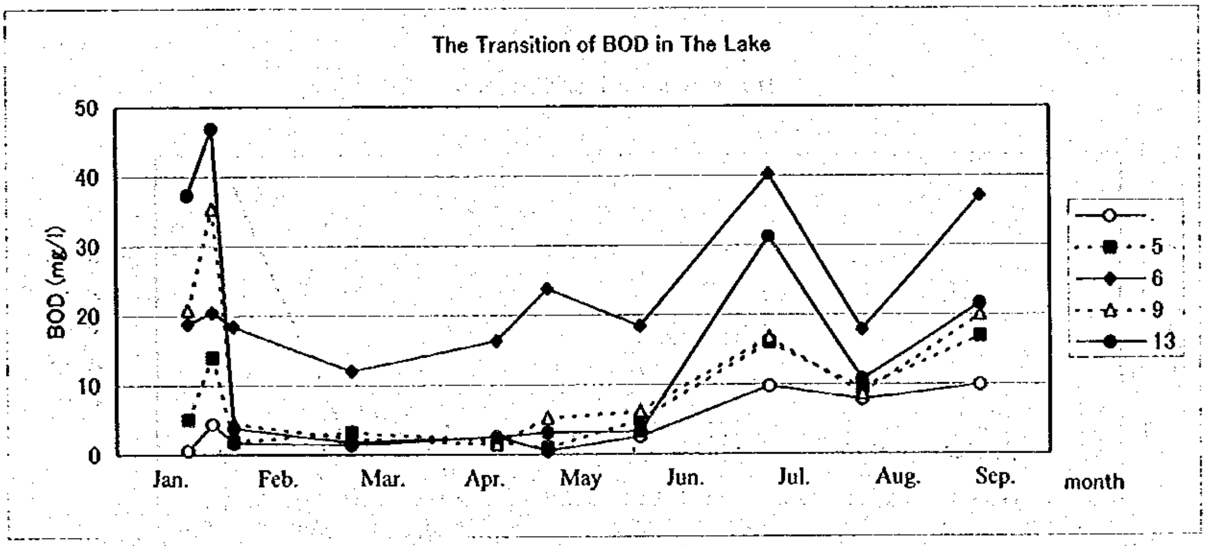


Figure III.3.12 The Transition of BOD in Puno Interior Bay

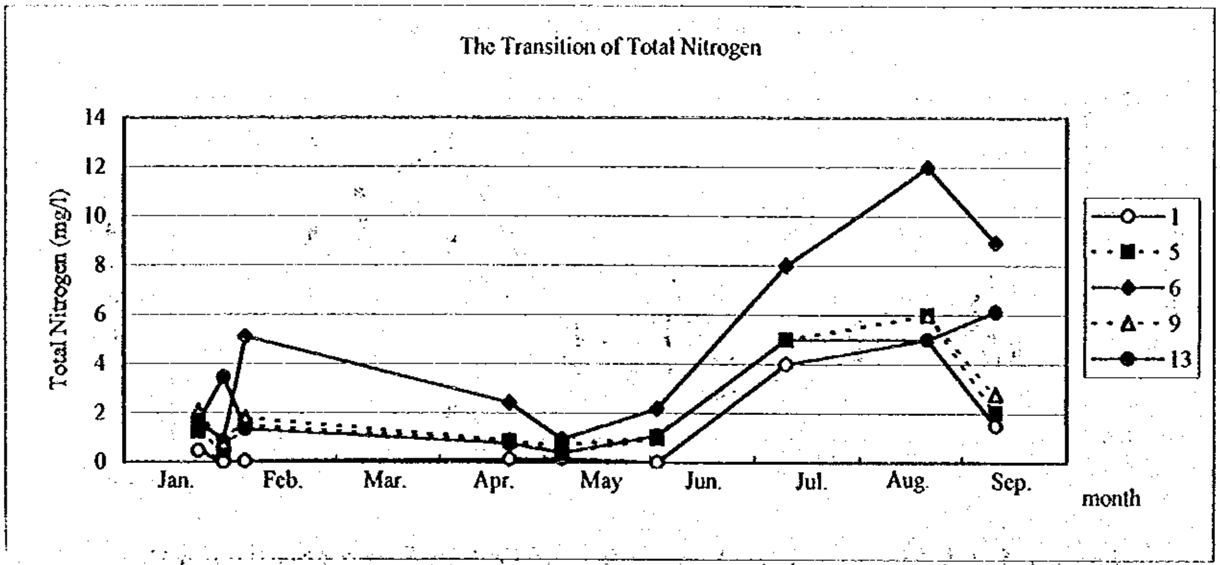


Figure III.3.13 The Transition of Total Nitrogen in Puno Interior Bay

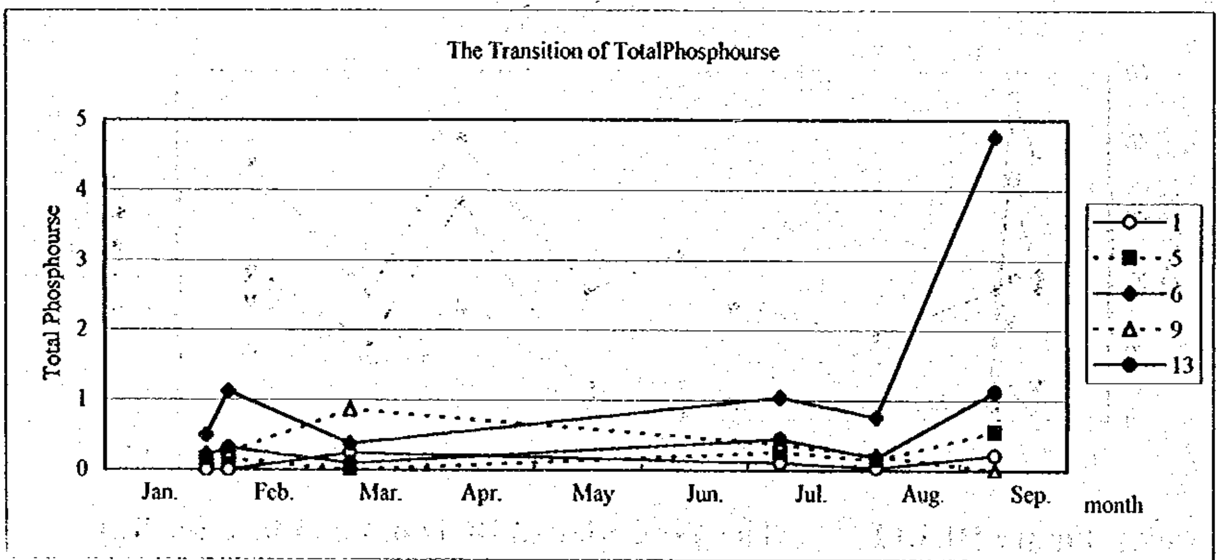


Figure III.3.14 The Transition of Total Phosphorus in Puno Interior Bay

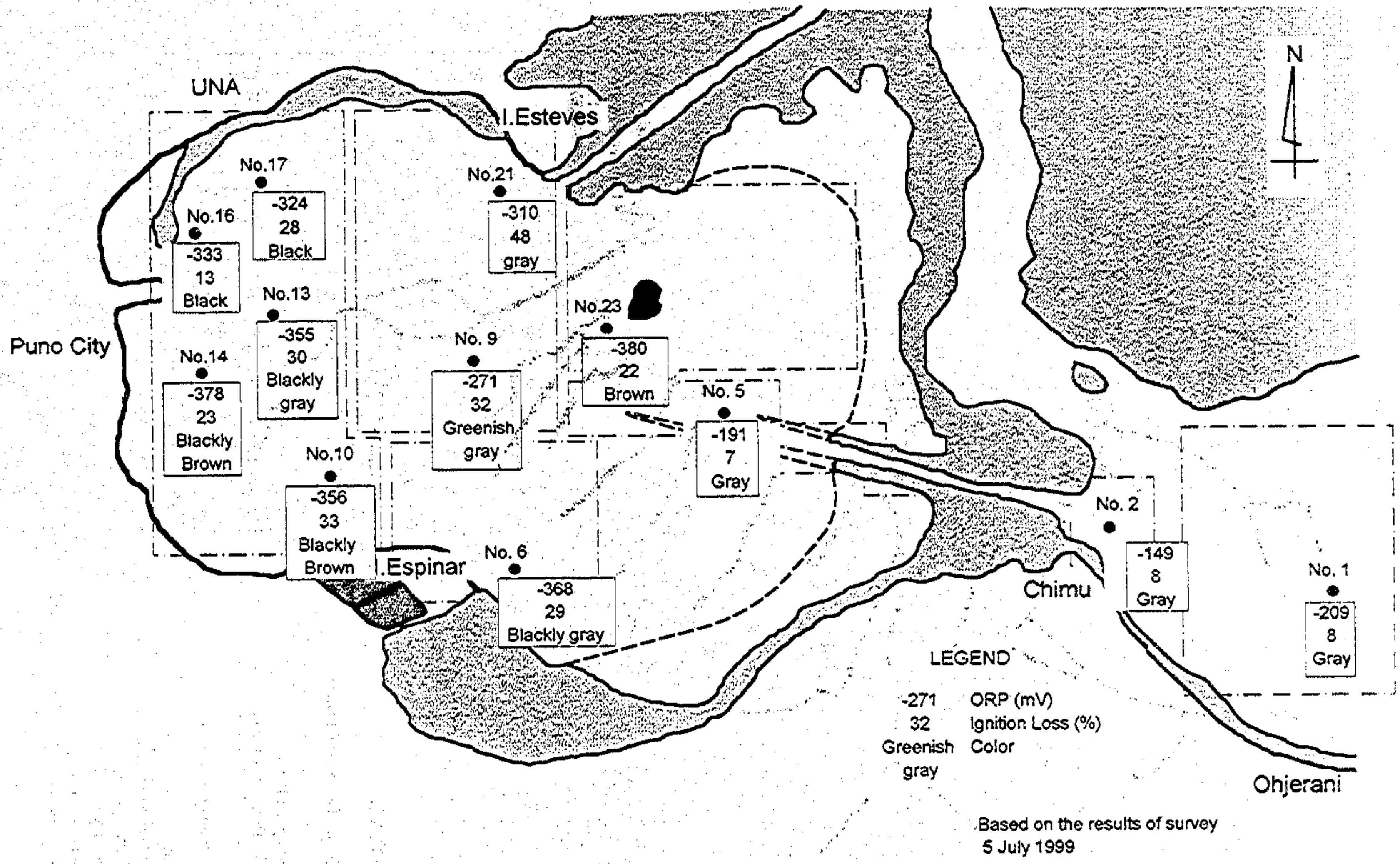


Figure III.3.15 The Regional Variation of Sediment Quality in Puno Interior Bay

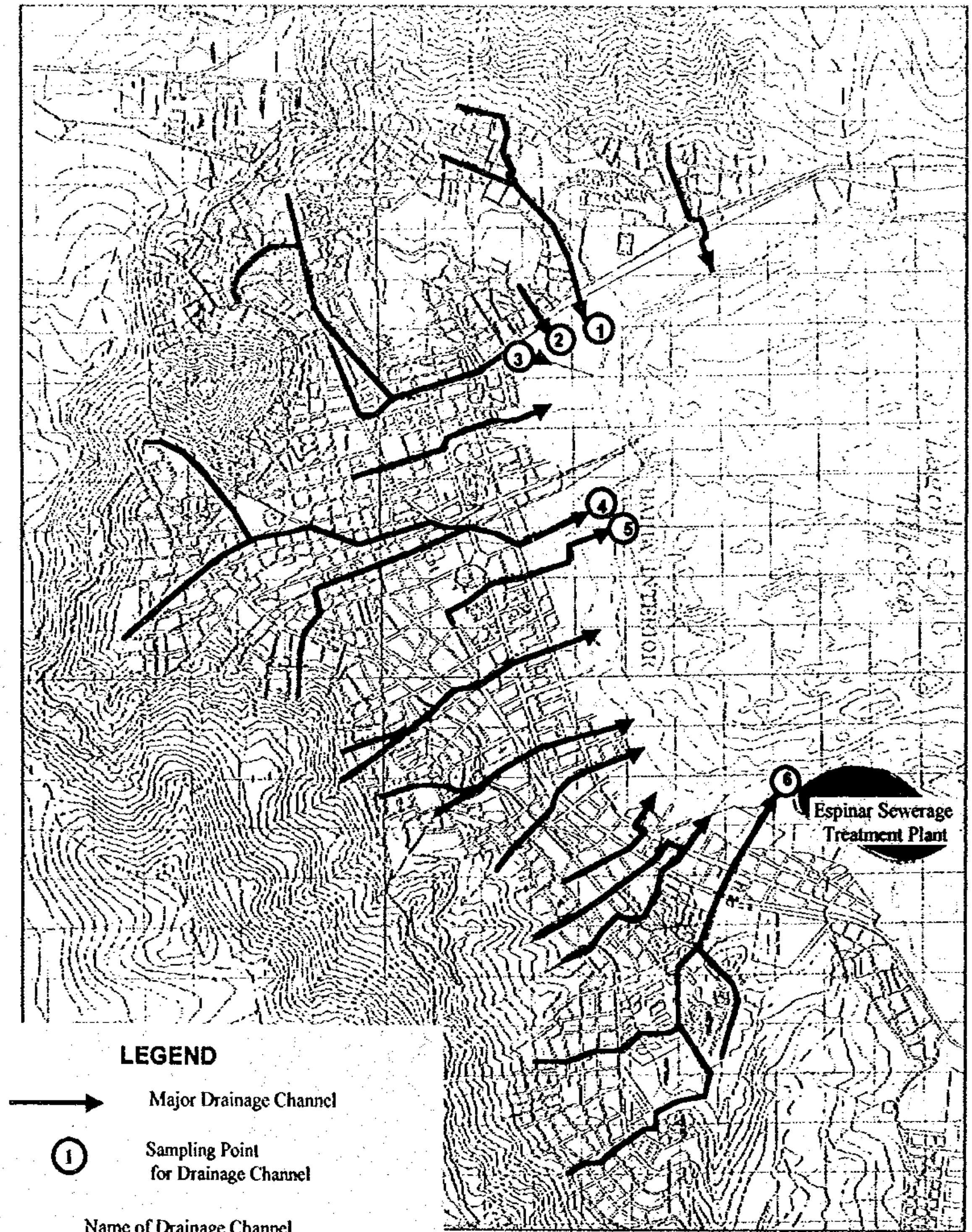
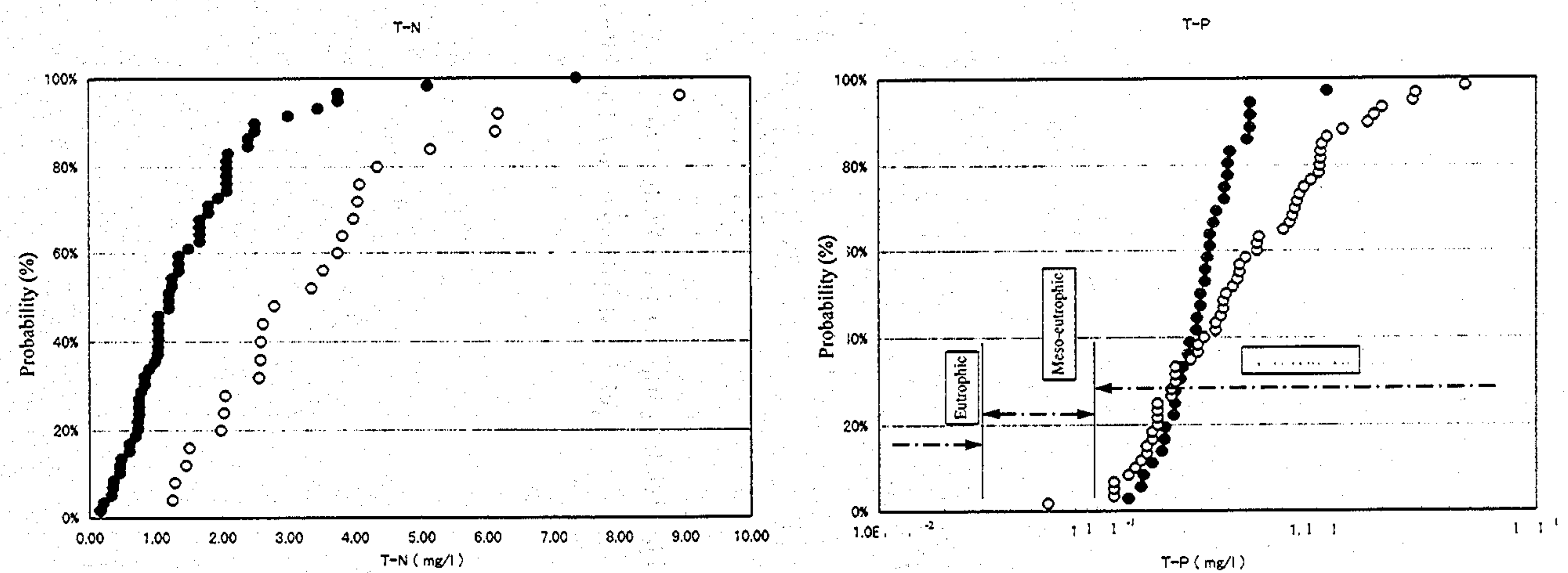


Figure III.3.16 The Location of Sampling Point for Drainage Channel Survey



note: T-N in the rainy season is inorganic nitrogen.

Source : Water Quality Syrvey by PELT and JICA (1999)

● Rainy season

○ Dry season

Figure III.3.17 The Level of Eutrophication in Puno Interior Bay (Existing)

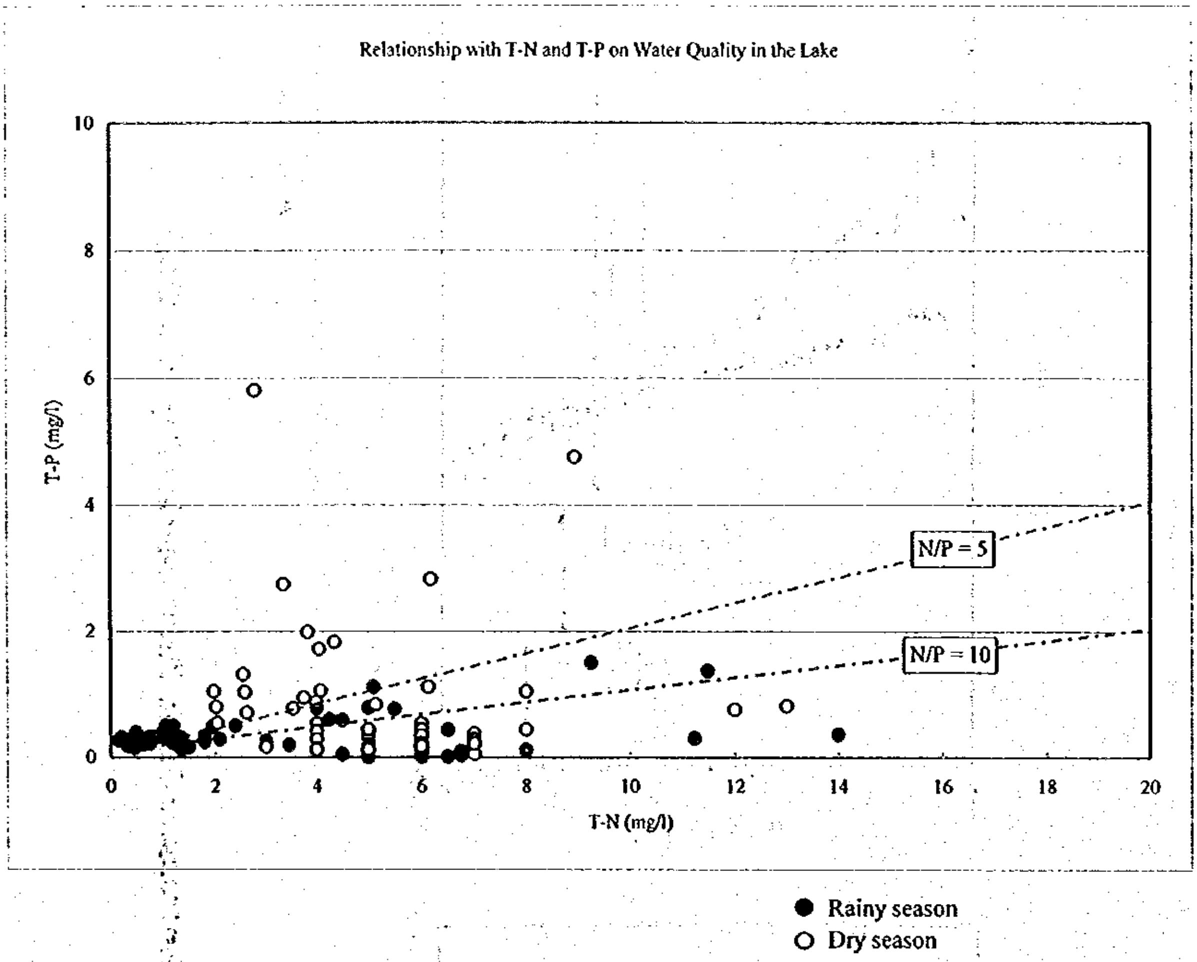
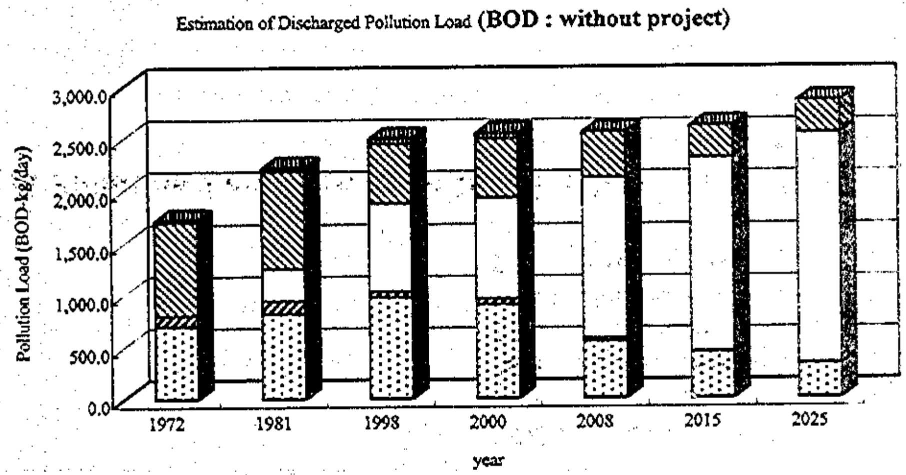


Figure III.3.18 **The Relationship between Water Quality of Total Nitrogen and Total Phosphorus**

BOD	Discharged Pollution Load into the Lake (kg/day)						
	Domesticwastewater	Commercial / Institutional wastewater	Sewerage Treatment Plant	Agricultural wastewater	Livestock wastewater	Solid Waste	Total
1972	699.8	105.7	0.0	-	896.1	20.0	1,721.6
1981	818.0	123.5	315.3	-	925.9	33.5	2,216.2
1998	976.1	55.4	844.3	0.0	568.0	54.5	2,498.3
2000	903.5	57.7	964.8	0.0	568.0	54.5	2,548.5
2008	545.4	33.4	1,536.7	0.0	444.1	0.0	2,559.6
2015	445.8	0.0	1,859.8	0.0	309.9	0.0	2,615.5
2025	331.5	0.0	2,209.7	0.0	309.9	0.0	2,851.1



T-N	Discharged Pollution Load into the Lake (kg/day)						
	Domesticwastewater	Commercial / Institutional wastewater	Sewerage Treatment Plant	Agricultural wastewater	Livestock wastewater	Solid Waste	Total
1972	66.8	10.1	0.0	2.1	430.4	6.4	515.8
1981	78.1	11.8	179.8	3.5	431.2	10.7	715.1
1998	93.2	5.3	481.5	5.6	262.3	17.4	865.3
2000	86.2	5.5	550.3	5.6	262.3	17.4	927.3
2008	52.2	3.1	876.2	5.6	205.1	0.0	1,142.2
2015	42.6	0.0	1,060.8	5.6	143.1	0.0	1,252.1
2025	31.7	0.0	1,260.3	5.6	143.1	0.0	1,440.7

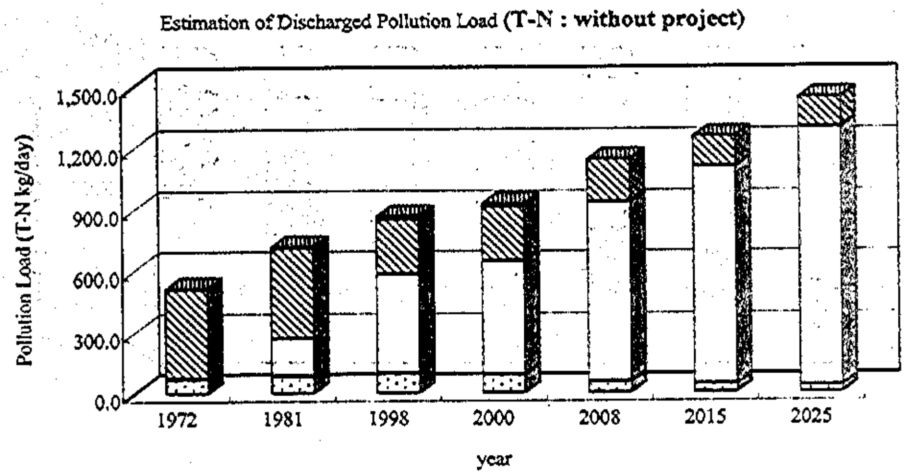


Figure III.4.1(1) Estimation of Discharged Pollution Load into Puno Interior Bay

T-P	Discharged Pollution Load into the Lake (kg/day)						
	Domesticwastewater	Commercial / Institutional wastewater	Sewerage Treatment Plant	Agricultural wastewater	Livestock wastewater	Solid Waste	Total
1972	25.3	3.8	0.0	1.0	71.1	1.0	102.2
1981	29.6	4.5	20.4	1.6	69.8	1.7	127.6
1998	35.3	2.1	54.8	2.6	44.4	2.8	142.0
2000	32.7	2.1	62.6	2.6	44.4	2.8	147.2
2008	19.7	1.2	99.9	2.6	34.6	0.0	158.0
2015	16.1	0.0	120.6	2.6	24.2	0.0	163.5
2025	11.9	0.0	143.2	2.6	24.2	0.0	181.9

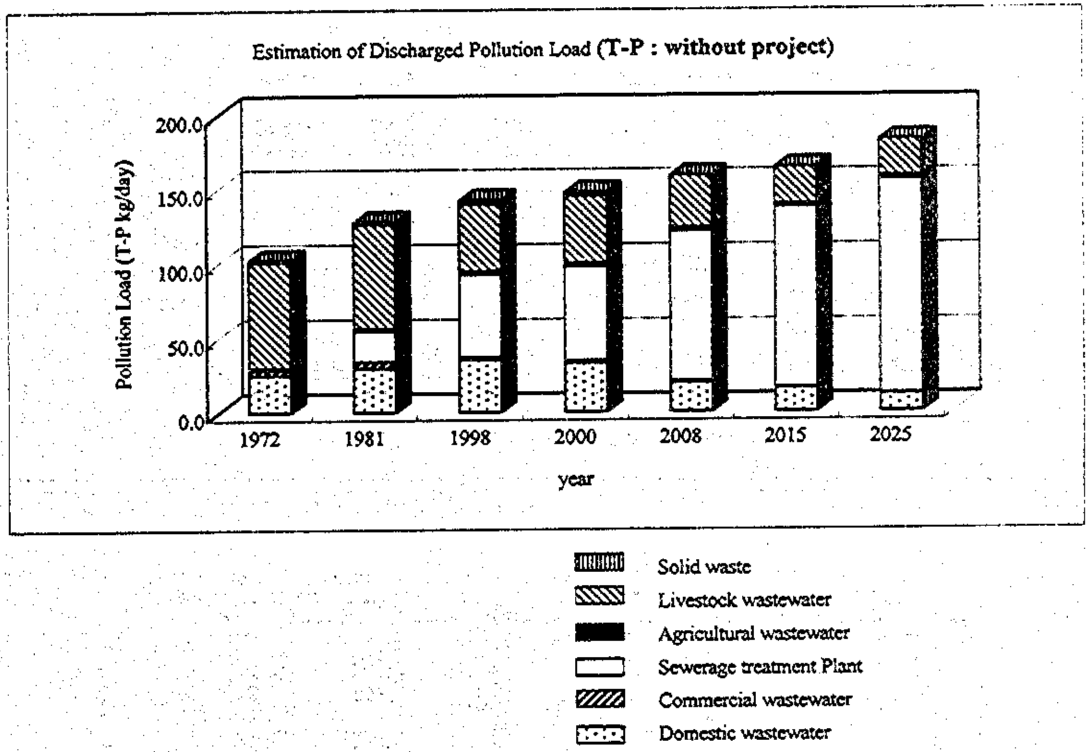
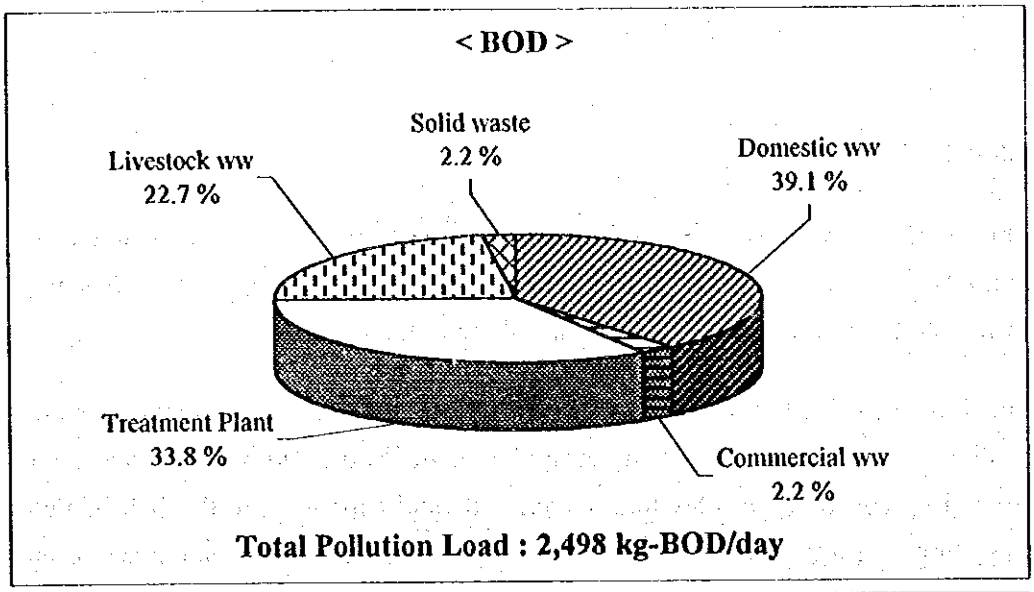
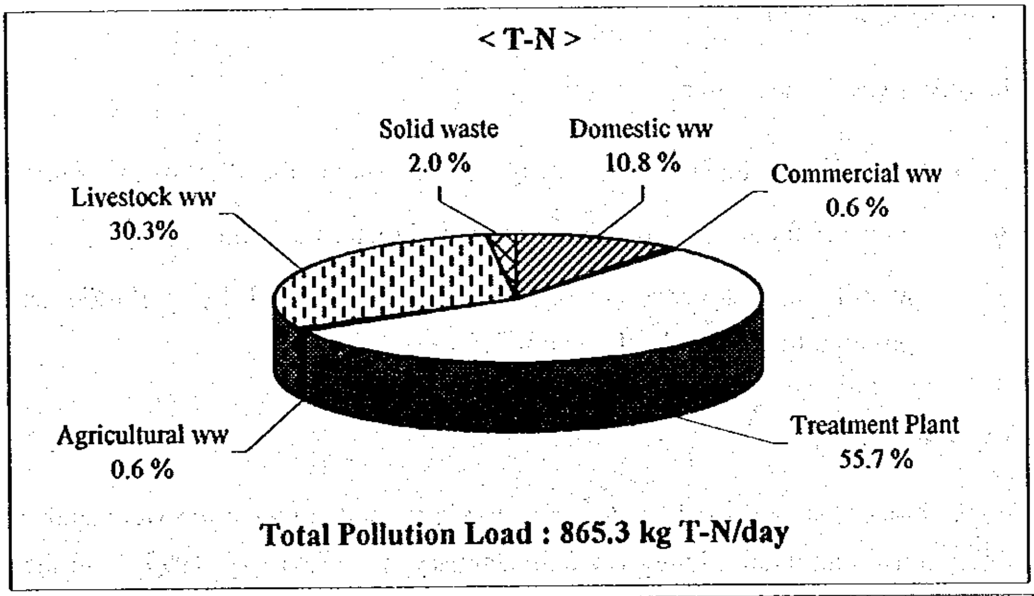


Figure III.4.1(2) Estimation of Discharged Pollution Load into Puno Interior Bay





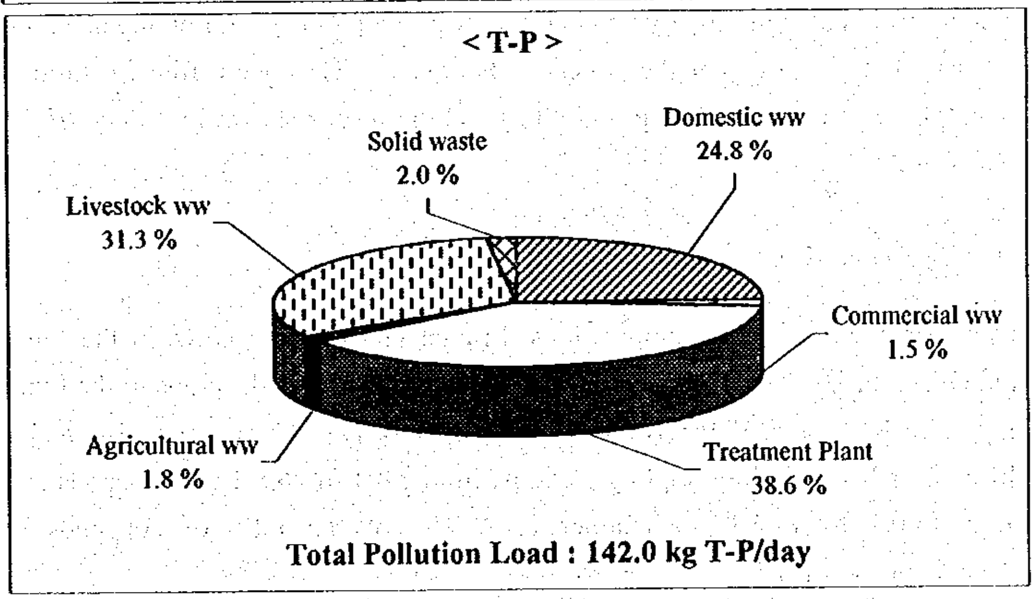


Figure III.4.2 Share of Discharged Pollution Load by Pollution Sources (Existing)

5. BIOLOGY

This section summarises the biological research carried out in Inner and Outer Puno Bay in January and February 1999, and makes some comparisons with earlier studies in the same areas and elsewhere in Lake Titicaca.

The biological studies carried out in Puno Bay include those on zooplankton, benthos, fauna of the macrophytes and aquatic birds. Other relevant topics studied by consultation, literature search and field trips include the fish of Puno Bay, trophic (nutrient) levels, the adjacent Lake Titicaca National Reserve and macrophyte distribution.

The objectives of these studies are to:

- describe the fauna and flora of Inner Puno Bay in the 1999 wet season;
- compare the fauna and flora of Inner and Outer Puno Bay;
- identify any adverse ecological conditions caused by pollution and possible future trends of change.

5.1 ZOOPLANKTON

Zooplankton (Copepoda and Cladocera) abundance and composition were studied in the Inner and Outer Puno Bays in January and February 1999. Surface samples were taken in January and depth profile samples (by hauling the plankton net from bottom to top of the water) in February. They were filtered through plankton nets (mesh size 280 μ and 40 μ) and the results shown in *Tables III.5.1 and III.5.2.*

Surface Zooplankton

The surface zooplankton compositions differed considerably between the Inner and Outer Bays. The average numbers of copepods and cladocerans in the Inner bay were 8.9/l and 38.0/l (total 46.9/l respectively. There were also major differences between the sampling stations, from 2.4/l to 26.8/l for copepods and from 13.0/l to 77.2/l for cladocerans. The overall ratio of copepods to cladocerans was 1:4.3.

In the Outer bay the average numbers of copepods and cladocerans were 4.4/l and 0.2/l respectively (total 4.6/l). As in the Inner Bay, individual sampling stations were highly variable with densities ranging from 0.2/l to 11.4/l for copepods and from zero to 0.6/l for cladocerans. The overall ratio of copepods to cladocerans was 22:1.

The total average population in the Inner Bay (46.9/l was larger than that of the Outer Bay (4.6/l). In the Outer Bay copepods outnumber cladocerans by 22:1, whilst in the Inner Bay cladocerans were relatively about 100 times more abundant than in the Outer Bay and outnumbered copepods by 4.3 times.

Bottom to Surface Zooplankton

Zooplankton numbers per litre in the Inner Bay again greatly exceeded those of the Outer Bay, by about 26 times (69.0/2.6) and 10 times (121.5/12.7)

respectively for samples taken with the 280 μ and 40 μ mesh nets. Total zooplankton numbers taken with the larger net (69.0/l) were about 57% of numbers taken with the smaller net (121.5/l). Estimates of zooplankton population sizes clearly depend on the size of sampling net used. The overall ratio of copepods to cladocerans was 1:7.8 for the larger net samples and 1:5.5 for the smaller net.

There were major differences in the estimates of population sizes at the different stations. For cladocerans these ranged from 1.7/l at Esteves Island to 171.8/l at Espinar Island (larger mesh size) and for copepods from 0.3/l (Esteves) to 23.6/l (jetty).

Population sizes in January and February cannot be compared with the available data. Zooplankton are not evenly distributed through the water column, tending to avoid the high surface light intensities and the low oxygen conditions near the bottom.

Table III.5.1 Zooplankton Abundance and Composition in the Surface Waters of Inner and Outer Puno Bay, January 1999

Sampling Station		Zooplankton Abundance (nos/l)		
		Copepods	Cladocerans	Total
Inner Bay				
1	Puno Port jetty	26.8	66.6	93.4
2	Esteves Island	4.8	16.6	21.4
3	Middle Bay	2.4	16.6	19.0
4	Espinar Island	4.8	77.2	82.0
5	Entrance to Navigation Channel	5.8	13.0	18.8
Inner Bay averages		8.9	38.0	46.9
Outer Bay				
1	Middle of bay	0.2	0	0.2
2	3 km from Chimu	2.4	0.4	2.8
3	2 km from Chimu	6.2	0	6.2
4	600 m from Chimu	11.4	0.6	12.0
5	Entrance to Navigation Channel	2.0	0.2	2.2
Outer Bay averages		4.4	0.2	4.6

Samples filtered through 280 μ mesh net.

Table III.5.2 Zooplankton Abundance and Composition of the Bottom to Surface Waters of Inner and Outer Puno Bay, February 1999

Sampling Station		Zooplankton Abundance (nos/l)		
		Copepods	Cladocerans	Total
Inner Bay				
1	Puno Port jetty	23.6 (33.3)	78.7 (121.5)	102.3 (154.8)
2	Esteves Island	0.3 (11.1)	1.7 (4.4)	2.0 (15.5)
3	Middle Bay	2.0 (18.1)	18.0 (88.4)	20.0 (106.5
4	Espinar Island	9.2 (18.9)	171.8 (270.7)	181.0 (289.6)
5	Entrance to Navigation Channel	3.9 (11.6)	35.6 (29.4)	39.5 (41.0)
Inner Bay averages		7.8 (18.6)	61.2(102.9)	69.0 (121.5
Outer Bay				
1	100 m from Entrance to Navigation Channel	0.6 (4.4)	2.0 (8.3)	2.6 (12.7)

- Samples collected by hauling plankton nets (280 µ and 40 µ mesh sizes) from bottom to surface;
- Figures in brackets derived from samples taken with 40 µ mesh nets;
- Samples of both net sizes collected from same locations and same date (9.2.99) and time

Muñiz *et al* (1989) found a total (January 1984) abundance of copepods and cladocerans of 223.5/l in Inner Puno Bay, an average figure for the whole water column. This is exceeded by the abundance (289.6/l) estimated with the smaller mesh net at Espinar Island. This total appears to be the highest recorded anywhere from Lake Titicaca. In the Lago Pequeño and Lago Grande of Lake Titicaca Pinto (1992) found mean maximum copepod and cladocera densities of 80-90/l in January/February 1982 and an absolute maximum (copepods only) of 175/l. In those parts of the lake copepods always outnumbered cladocerans.

There are seven species of copepods recorded from Lake Titicaca (Pinto, 1992) and 31 species of cladocerans (Rey, 1992). Species collected in this study will be identified by experts and discussed in later reports.

5.2 BENTHOS

Benthos samples were collected from three transects in the Inner Bay and one in the Outer Bay. They were taken with an Ekman grab and the results (averages of 2 or 3 samples at each point) are shown in *Tables III.5.3, III.5.3.4* and *III.5.3.5*.

The results show marked differences between the transects. In transect 1 from Inner Puno Bay, benthic organisms were virtually absent. At all of these points submerged macrophytes were absent and the bottom sediments of fine black muds smelt strongly of hydrogen sulphide, indicating strongly anaerobic conditions unsuitable for benthic macroinvertebrates. In Outer Puno Bay benthos was more abundant with molluscs, *Hyalella* spp and Hirudinea (leeches) being the most common. At most of these sampling points the muds were moderately to strongly anaerobic, indicating moderate to poor conditions for the benthos.

Benthic macroinvertebrates were most abundant in the transects across the dense macrophyte beds of the Inner Bay (mainly *Potamogeton strictus* with small amounts of *Myriophyllum elatinoides*). In the beds themselves the most abundant species were the molluscs *Taphius montanus* (maximum 2,375/m^2) and *Littoridina* spp (maximum 1800/m^2), amphipods *Hyalella* spp (maximum 1800/m^2) and oligochaetes (1900/m^2). Within the macrophyte beds chironomids occurred in low numbers, but up to 10,915/m^2 in the shallow vegetation-free waters between the macrophytes and the shore. At all sampling points in the northeast and southeast corners the mud sediments were light brown with little or no hydrogen sulphide, indicating aerobic conditions favourable for benthos. The lake waters of these areas were also considerably clearer than those of the central and other areas of Inner Puno Bay.

Table III.5.3 Benthos Densities from Transect 1 (Inner Puno Bay), January 1999

	Sampling Station and Density (nos/m^2)			
Type	1	2	3	5
Oligochaeta	0	0	0	0
Hirudinea	0	0	0	133
Tricladida	0	0	0	0
Mollusca				
Taphius montanus	0	83	0	50
Littoridina spp	0	17	0	0
Amphipoda				
Hyalella spp	0	0	0	583
Insecta				
Chironomidae	0	100	33	0

Station 1: Puno Port; Station 2: Esteves Island; Station 3: Middle of Bay; Station 5: Entrance to Navigation Channel

Table III.5.4 Benthos Densities from Transect 2 (Outer Puno Bay), January 1999

	Sampling Station and Densities (nos/m^2)						
Type	1	2	3	4	5	6	7
Oligochaeta	0	0	0	0	0	0	0
Hirudinea	50	583	583	0	50	33	533
Tricladida							
Euplanaria dorotocephala	17	0	0	0	0	0	0
Mollusca							
Trophius montanus	0	0	17	0	83	0	0
Littoridina spp	17	217	33	17	167	33	33
Anisancylus crequii	0	133	33	0	0	0	0
Sphaerium sp	33	33	83	50	83	517	317
Amphipoda							
Hyalella spp	267	1317	1650	67	83	317	150
Insecta							
Chironomidae	0	0	17	0	0	33	17

Also found: Hydra sp and sponge colonies
Station 1: 100 m offshore Chimu water abstraction plant; Station 2: 150 m offshore from Ojerani; Station 3: 100 m offshore from Sallihua; Station 4: 400 m offshore from Ojerani; Station 5: 300m offshore Uros tourist village; Station 6: 70 m offshore halfway between Uros tourist village and Navigation Channel; Station 7: halfway along Navigation Channel

Table III.5.5 Benthos Densities from the Macrophyte Beds of the South East (A) and North East (B) Corners of Inner Puno Bay, February 1999

A. South East Corner

	Sampling Station and Density (nos/m²)						
Type	1	2*	3*	4*	5*	6	7
Oligochaeta	125	350	800	1500	1900	385	765
Hirudinea	0	0	25	200	50	135	35
Tricladida	0	0	0	0	0	0	0
Mollusca							
Taphius montanus	0	250	325	800	2375	1715	100
Littoridina spp	0	0	25	150	1800	1215	235
Anisancylus crequii	0	0	0	0	0	165	34
Amphipoda							
Hyalella spp	0	200	200	1775	1600	1785	65
Insecta							
Chironomidae	175	1200	150	25	25	6485	8500

Transect from half way between Espinar Island to 50m from shore in south east corner, samples at regular intervals. * Dense beds of submerged macrophytes

B. North East Corner

	Sampling Station and Densities (nos/m²)						
Type	1*	2*	3*	4*	5	6	7
Oligochaeta	1035	85	35	685	35	0	0
Hirudinea	0	0	15	115	65	135	0
Tricladida							
Euplanaria dorotocephala	0	0	0	15	0	0	0
Mollusca							
Taphius montanus	150	400	335	650	315	100	0
Littoridina spp	0	35	15	935	150	215	0
Amphipoda							
Hyalella spp	700	235	950	1100	800	800	0
Insecta							
Chironomidae	100	35	50	35	2635	10915	5215

Transect from 50m east of Diablo Island to within 30m from shore in north east corner, samples at regular intervals. * Dense beds of submerged macrophytes

The virtual absence of benthos from much of Inner Puno Bay confirms the earlier findings of Ocola and Torres (1997). The high densities in the submerged macrophyte beds of the eastern side of the Inner Bay is the first time that high benthos populations have been found in Inner Puno bay. These areas cover a significant part of the bay. The densities recorded in Transect 1 of the Inner Bay are lower than those found by Morales *et al* (1989) in 1982 in similar locations. They are also lower than those found by Dejoux (1992) in various localities of the Lago Grande and Lago Pequeña areas of Lake Titicaca. However the high numbers found in the sediments of the submerged macrophyte beds and the shallow muds behind them are amongst the highest macroinvertebrate densities recorded in Lake Titicaca (Dejoux, 1992).

Clearly, benthic conditions are very variable in Inner Puno Bay, ranging from virtually intolerable for life to those in which some species can flourish in very high numbers. This is particularly so for chironomid larvae, which can live in a wide variety of conditions including low oxygen levels. The benthic fauna of the submerged macrophyte areas is undoubtedly very important for Inner Puno Bay and is indicative of the communities that must have been found at one time over nearly all of the Inner Bay.

5.3 FAUNA OF THE MACROPHYTES

The submerged macrophyte beds of Inner and Outer Puno Bay provide attachment, food and shelter for a variety of macroinvertebrates. In turn, these provide food for the fish that live in and utilise these areas.

The macroinvertebrate populations of the submerged macrophyte beds were studied in February 1999. Two large samples (about 500g) of macrophytes (mainly *Potamogeton strictus* with small amounts of *Myriophyllum elatinoides*) were taken from the upper 20-30 cm of dense growths in the northeast corner of Inner Puno Bay. In the Outer Bay, similar sized samples (about $^2/_3$ *Myriophyllum elatinoides* and $^1/_3$ *Potamogeton strictus* were taken close to the shore between the navigation channel and Uros village. The macroinvertebrates of all four samples were identified and counted and their densities expressed as numbers per 100 g of dry macrophyte (*Table III.5.6*)

Macroinvertebrates were abundant on the macrophytes. The dominant species in the Inner Bay were *Taphius montanus* (318 and 518/100 g dry weight of macrophyte) and *Hyalella* spp (177 and 291/100 g dry weight of macrophyte). *Hyalella* spp were also abundant at Outer Puno Bay (360 and 392/100 g of dry weight macrophyte) with *Littoridina* spp as the dominant mollusc (280 and 101/100 g dry weight macrophyte). Few other species were recorded and always in small numbers.

The standing biomass of the macrophytes was not measured, but was clearly considerable at the time and place of sampling. Iltis and Mourguiart (1992) recorded a dry weight biomass for *Potomogeton strictus* in Puno Bay of 267 g/m^2. Using this figure, the densities of *Hyalella* spp and *Taphius montanus* in the Inner Bay macrophyte beds can be calculated as ranging from 473-777/m^2 and 849-1383/m^2 respectively. The same assumptions and calculations for *Hyalella* spp and *Littoridina* spp in the Outer Bay give density estimates of 961-1047/m^2 and 270-748/m^2 respectively. These values are similar to higher values found for these species in the benthos. Clearly therefore fauna living on the submerged macrophytes is of major significance, not least as fish food.

Table III.5.6 Abundance of Macroinvertebrates on the Macrophytes of Inner and Outer Puno Bay, February 1999

Species	Number/100 g of Dry Weight Macrophyte*			
	Inner Puno Bay		Outer Puno Bay	
	Sample 1	Sample 2	Sample 1	Sample 2
Crustacea				
Hyalella spp	291	177	360	392
Mollusca				
Ancylus crequii	0	0	49	14
Littoridina spp	0	0	280	101
Taphius montanus	518	318	6	1
Leeches	5	0	6	3
Planarians	6	9	0	0
Corixid	2	0	0	0

* Dry weight estimated as 12.7% and 13.5% of fresh weights for Inner and Outer Puno Bays respectively

5.4 PHYTOPLANKTON

The composition, abundance and productivity of phytophankton can be good indicators of nutrient levels (especially nitrogen and phosphorous) and pollution. Despite this, and perhaps because of technical difficulties, the phytoplankton of the Inner Puno Bay is not well researched. Cornejo *et al* (1991) demonstrated that (in the late 1980's) phytoplankton was uniformly distributed through the water column with respect to chlorophyll *a* concentrations, whilst numbers decreased with depth. In both the Inner and Outer Bays chlorophytes (green algae) comprised 50-60% of total numbers, with diatoms and cyanophytes (blue-green algae) of lesser importance. Phytoplankton was generally most abundant in the dry season, particularly the genera *Oscillatoria* and *Anabaena* (green algae).

In the late 1990s Ocola and Torres (1997) described the relative composition of the Inner Bay's phytoplankton (*Table III.5.7*). Green algae were the most abundant (80.12%) with diatoms and desmids of secondary importance. Two genera (*Scenedesmus* and *Ulothrix* made up half of all the phytoplankton. These later results show changes (eg. increased green algae, absence of blue-greens) from the 1980s. More intensive sampling is required to show if such changes are permanent or due to short term variations.

In January and February 1999 the waters of Inner Puno Bay (and particularly near the western shores) were noticeably green in colour, indicating high phytoplankton numbers. Such discoloration is typical of highly eutrophic waters in which high nutrient concentrations can support very high phytoplankton populations. Water in Outer Puno Bay showed no such signs.

Besides being an indicator of abnormally high nutrient levels, excessive populations can cause disruption to lake ecosystems. This can occur through the shading effect of high numbers which reduces the light levels towards the bottom of the lake thereby eliminating submerged macrophytes. Additionally, the death and decay of phytoplankton, particularly if occurring suddenly, can cause significant and rapid reductions in dissolved oxygen levels, leading to sudden fish mortalities (fish kills). These have occurred in the Inner Puno Bay and the huge decreases in submerged vegetation are probably partly attributable to high phytoplankton numbers.

In Lake Titicaca, the overall number of phytoplankton species (about 260) is low considering its age, size and habitat diversity. About 90% of species belong to the chlorophyte (greens), cyanophytes (blue-greens) and diatom groups. The blue-greens are generally the most common species. Most species are cosmopolitan (found world-wide) with only 5% being restricted to tropical areas. Only about 13 species are endemic (Iltis, 1992a).

In the main parts of Lake Titicaca (Lago Grande and Lago Pequeño) blue-greens and greens make up most of the biomass. Phytoplankton densities up to 8 million cells per litre have been recorded and biomasses up to 4054 mg/m^3, 180 mgC/m^3 and 5.9 mg chlorophyll *a* (Iltis, b). Richerson *et al* (1992) reported average primary production levels in the Lago Grande of 1.13 gC/m^2/day, 0.56 gC/m^2/day in Lago Pequeño and 0.82 gC/m^2/day in Outer Puno Bay. Biomass and productivity figures will be much higher in Inner Puno Bay.

Table III.5.7 Composition of Phytoplankton in Inner Puno Bay (Polluted Sites by Hospital and Espinar Island), August 1997

Organism	Occurrence (%)
Chlorophytes	**(80.12)**
Chroococales	
Chroococcus	8.84
Gleocapsa	10.65
Merismopedia	0.38
Oscillatoriaceae	
Oscillatoria	0.54
Anabaena	1.62
Hydrodyctiaceae	
Pediastrum	4.28
Palmellaceae	
Scenedesmus	24.24
Solanastrum	3.99
Crucigenia	0.48
Oedogoniales	
Ulothrix	25.1
Desmidaceae	**(2.66)**
Renium	0.19
Closterium	0.57
Staurastrum	0.38
Cosmarium	1.52
Diatomaceae	**(15.45)**
Tabellaria	0.48
Asterionella	11.78
Synadra	0.29
Navicula	2.9
Protozoa	

Source: Ocola and Torres (1997)

5.5 AQUATIC BIRDS

Lake Titicaca is renowned world-wide for its aquatic birds and large numbers occur in the totora beds that make up much of the nearby lake Titicaca National Reserve. Large numbers of birds also occur in Inner Puno Bay and a short study of them has been made to determine if its polluted condition has in any way affected them.

A total of 41 species of residential and migratory aquatic birds are recorded from the Lake Titicaca National Reserve (*Table III.5.8*). Most or all of them can be expected to occur, or have occurred, in Inner Puno Bay. In 1992 and 1993, Canales (1998) recorded the numbers of migratory birds occurring in Inner Puno Bay and other nearby locations (*Table III.5.9*). It is clear therefore that Inner Puno Bay is an important locality for migratory birds.

On February 6 1999 a survey of birds was made in Inner Puno Bay. A total of 18 species was seen in a 3-hour period and together with two other species seen on other occasions, 20 of the 41 aquatic birds of Lake Titicaca have been seen in a very short period. This again emphasises the importance of Inner Puno Bay for birds. Nearly all of the birds seen were close to the shore, particularly between the UNA campus and Espinar Island and the northeast and southeast corners of the Inner Bay. The former areas are the bay's most polluted areas and many birds were seen feeding in places where sewage drains discharge directly to the water. The most numerous birds were *Phalaropus tricolor* which occurs in the eastern part of Inner Puno Bay, feeding amongst the beds of submerged macrophytes which occur there.

Canales (personal communication, February 1999) reported that several species of aquatic birds that used to occur in the Inner Bay no longer do so. These include *Centropelma micropterum*, *Gallinago gallinago*, and *Podiceps occipitalis*. On the other hand, two species of birds have become more common in recent years - *Phalaropus tricolor* and *Phoenicopterus chilensis*.

Table III.5.8 Aquatic Birds of the Lake Titicaca National Reserve

	R	M	Local Name	English Name
Podiceps occipitalis	R		Zambullidor	
Rollandia rolland *	R		Zambullidor	White-tufted grebe
Centropelma micropterum	R		Ninra, maca alicorto	Short-winged grebe
Phalacrocorax olivaceus *		M	Mehke	Olivaceous cormorant
Phoenicopterus chilensis *		M	Flamenco, Pariguana	Chilean flamingo
Egretta thula *		M		Egret
Bubulcus ibis	R			
Casmerodius albus		M	Garza blanca	
Nycticorax nycticorax	R		Pájaro bobo	Night heron
Plegadis ridgwayi *			Cuervillo de la puna	Puna ibis
Lophonetta specularioides	R			
Anas flavirostris *	R		Pato barcino	Speckled teal
Anas versicolor *	R		Pato puna	Puna teal
Anas georgica *	R		Pato cola agunda	Yellow-billed pintail
Anas cyanoptera *	R		Pato ala azul	Cinnamon teal
Oxyura ferruginea *	R		Pato zambullidor	Andean ruddy duck
Rallus sanguinolentus *	R		Gallineta commún	Plumbeous rail
Gallinula chloropus *	R		Gallineta de agua	Moorhen
Fulica americana *	R		Ajoya	American coot
Fulica ardesiaca	R		Choka	
Fulica gigantea	R		Choka, Ajoya	Giant coot
Phalaropus tricolor *		M	Falaropo tricolor	Wilson's phalarope
Recurvirostra andina		M		
Himantopus himantopus		M	Ccota-año	Common stilt
Vanellus resplendens *	R		Tero serrano	Andean lapwing
Pluvialis dominica		M		
Charadrius alticola		M	Chorlito serrana	Puna plover
Tringa flavipes *		M	Chorlo patas amarillas	Lesser yellow legs
Tringa melanoleuca		M	Chorlo mayor patiamarillo	Greater yellow legs
Actitis macularia		M		
Calidris mauri		M		
Calidris sp		M		
Calidris bairdii *		M		
Calidris melanotus		M		
Gallinago gallinago		M	Sak'a-Sak'a	Puna snipe
Larus pipixcan		M	Kellwa, Gaviota andina	Franklin's gull
Larus serranus *		M	Gaviota menor	Andean gull
Cinclodes fuscus	R			
Phleocryptes melanops *	R		Totorero	Wren-like rushbird
Tachuris rubrigastra	R		Siete colores	Many coloured rush tyrant
Lessonia rufa *	R		Negrito	Rufous-backed negrito

* Birds seen, mainly on 6th February. R: Resident; M: Migratory

Table III.5.9 Numbers of Migratory Birds in Inner Puno Bay and Three Localities in Outer Puno Bay, 1992 and 1993

Locality	Total numbers of Migratory Birds	
	1992	1993
Inner Puno Bay	5089	1283
Chejoña, Outer Puno Bay	2857	1659
Paucarcolla, Outer Puno Bay	7324	3352
Lake Titicaca National Reserve, Outer Puno Bay	3074	2746
Total	18,344	9,040

Source: Canales, 1998

5.6 MACROPHYTES OF INNER PUNO BAY

The macrophytes of Inner Puno Bay have been most recently studied by Ocola and Chambi (1995), and Ocola and Torres (1997), whilst earlier studies include those of Collot (1981) and Cornejo *et al* (1989). More than 15 species of macrophytes occur in Lake Titicaca, most or all of which occur in Outer Puno Bay and at least eight have been recorded from Inner Puno Bay (*Table III.5.10*).

Figure xx shows the most recently mapped distribution of macrophytes (1997) in the Inner Bay. Emergent totora (*Schoenoplectus tatora*) occupies a broken fringe around the perimeter whilst submerged macrophytes (mainly *Potamogeton strictus* with lesser amounts of *Myriophyllum elatinoides*) are mainly restricted to the northeast and southeast corners. The present distribution is clearly much reduced from earlier times. Thus Cornejo *et al* (1989) reported that totora declined from covering 70% of Inner Puno Bay in 1937 to 16.3% in 1980, whilst Ocola and Torres (1997) estimated its abundance in 1997 to be 363 ha, about 21% of the Inner Bay. Other species have declined also and estimates are shown in *Table III.5.11*. In total, the amounts of submerged macrophytes are estimated to have declined by 65% between 1981 and 1997.

One type of floating macrophyte, *Lemna* (lenteja de agua) has increased in recent years. Although present in the Inner Bay and common in the early 1980s (Cornejo *et al*, 1989), it increased to very high levels in the middle 1990s (Ocola and Chambi, 1995). Between 1993 and 1995 it covered up to 360 ha (21%) of the Inner Bay, but had declined to 90 ha in September 1997. In January/February 1999 *Lemna* still covered a much smaller area than in the early/middle 1990s.

Table III.5.10 The Macrophyte Taxa of Lake Titicaca

Submergent	Floating	Emergent
**Chara* spp	*Azolla filiculoides*	*Hydrocotyle ranunculoides*
Nitella clavata	**Lemna gibba*	*Lilaeopsis andina*
**Sciaromium* sp	**Lemna* sp	*Ranunculus trichophyllus*
**Elodea potamogeton*		**Schoenoplectus tatora*
**Myriophyllum elatinoides*		
**Potamogeton strictus*		
Ruppia maritima		
Zanechellia palustris		

Source: Cornejo *et al*, 1989.
*Occur in Inner Puno Bay. Other species may also occur in small amounts.

Table III.5.11 Levels of Macrophyte Cover in Inner Puno Bay, 1981 and 1997

Species	Level of Cover (ha)		% Decline
	1981	1997	
Chara spp	120	0*	100
Elodea potamogeton	138	ns	100
Myriophyllum elatinoides	207	95	54
Potamogeton strictus	715	52	93
Schoenoplectus tatora	541	363	33

Source: Ocola and Torres (1997)
* recorded in small amounts by surveys undertaken in this study in February 1999
ns: not significant

5.7 Trophic Levels in the Inner Bay

Lake Titicaca is for the main part an oligotrophic lake, with low levels of plant nutrients, particularly nitrogen and phosphorus. Studies in Inner Puno Bay (Northcote *et al*, 1989; PELT, 1994) have shown that it has very much higher nutrient levels than the rest of the lake. *Figure xx* shows the trophic (nutrient) levels in the Inner Bay in 1995, based on levels of Total Phosphorus (Total P) in its waters at that time.

Thus in the middle 1990s, trophic conditions in Inner Puno Bay varied from meso-eutrophic (10-30 μg/l Total P) to hyper-eutrophic (>100 μg/l Total P). The best (meso-eutrophic) conditions were found along the eastern shores whilst the worst (hyper-eutrophic) existed along the southern, western and northern shores.

These are the areas that receive partially treated waste waters from the Espinar treatment lagoons and flows of untreated sewage wastes and rainfall run-off. The great majority of the Inner Bay was classified as eutrophic (Total P 30-100 μg/l).

The high trophic status of the Inner Bay has caused many changes to its chemical, physical and biological conditions.

5.8 FISH OF THE PUNO BAY

The fish fauna of Lake Titicaca presently consists of native fish - 18 or more species of *Orestias* (carachi, ispi) and two species of *Trichomycterus* (sucha, catfish) - and two introduced species: *Basilichthys bonariensis* (pejerrey) and *Salmo gairdneri* (rainbow trout, trucha).

In the early 1980s Treviño *et al* (1984) recorded four species of *Orestias* in Inner Puno Bay: *O. olivaceus* (carachi enano), *O. ispi* (ispi), *O. luteus* (carachi amarillo) and *O. agassii* (carachi gris) and the pejerrey. In the middle 1990s (Ocola and Torres, 1997) only the pejerrey, carachi amarillo and carachi gris were caught. The two species no longer found in the Inner Bay (carachi enano and ispi) still occur in the Outer Bay.

The comparative growth rate of carachi amarillo was lower in Inner Puno Bay than in the Outer Bay (Ocola and Torres, 1997). This suggests that conditions are less favourable for it in the Inner Bay. Conditions generally seem to be poor for fish in this area as the average annual yield is only 56 kg/ha. Likewise, fish catches are estimated to have declined by 65% in the last 20 years. The pejerrey eats mainly zooplankton, which is abundant in the Inner Bay, and the present conditions are believed to be favourable for this species.

5.9 LAKE TITICACA NATIONAL RESERVE (LTNR)

The LTNR was declared on 31 October 1978 and covers 36,180 ha, of which 29,150 ha are in the northern part of Outer Puno Bay and the remainder in the north of Lake Titicaca. The Puno Bay sector's boundary follows the shoreline of the Inner Bay's northeast corner, down to the Outer Bay end of the main navigation channel, and thereafter includes virtually all of the extensive totora beds of northern Puno Bay. The LTNR has more than 60 species of bird, including some in danger of extinction. In total, the LTNR is believed to contain about 50% of the whole of Lake Titicaca's birds and wildlife.

In recognition of the LTNR's national and international significance, it was declared a RAMSAR site on 20th January 1997. The RAMSAR Convention is one of the most powerful and influential of international wildlife protection measures. National governments are obliged by the Convention to undertake all reasonable measures to protect its declared sites - such as the LTNR. Up to the present time the only recorded impact of conditions in the Inner Bay has been the presence of large amounts of *Lemna* in the LTNR's river Huile (Willy). This decomposed to given unpleasant odours and presumably localised and short term negative effects on the river's fauna and flora.

5.10 BIOLOGICAL PROBLEMS

There are undoubtedly biological problems in the Inner Puno Bay. These are at least partially caused by factors beyond the control of any authority:

(i) the high altitude of Lake Titicaca means that there are naturally low oxygen levels in the water at saturation levels - approximately 65% of that at sea level. Thus the Inner Bay is more liable to suffer low oxygen levels and oxygen depletion than lakes at lower altitude. A level of biological activity that depletes the Inner Bay's waters of oxygen would not necessarily do so at lower altitudes;

(ii) the waters of Inner Puno Bay are, because of their shallow depth, comparatively warm. They therefore hold less oxygen than the colder waters of Outer Puno Bay, thus being more liable to suffer depletion;

(iii) the tropical latitudes of Lake Titicaca ensure that it receives a high year-round level of radiation (enhanced by low cloud levels), thereby providing the energy for continuously high levels of biological activity and oxygen consumption;

(iv) the virtually enclosed nature of the Inner Bay (turnover periods estimated at 18-64 years), with minimal water exchange with the Outer Bay via the two navigation channels. All materials and substances entering the Inner Bay tend to stay there and accumulate. On the positive side this barrier (of alluvial sediments) prevents contamination from entering the Outer Bay.

The above four factors therefore pre-dispose the Inner Bay to pollution problems. So far as biological problems are concerned, the following are the principal ones:

- loss of species and decline in abundance of submerged macrophytes (and their attached fauna), due principally to low light levels and low oxygen content of deeper water and muds;

- loss of benthos over much of the lake, caused by low oxygen conditions in the deeper waters and bottom sediments;

- loss of fish spawning and nursery areas, due to loss of macrophytes;

- loss of fish species and abundance;

- high nutrient status of the water to the extent that over-production of phytoplankton occurs - effects resulting from this are loss of water clarity, excessive oxygen consumption on their death and decay, and consequent adverse effects on submerged macrophytes, zooplankton and fish abundance and composition;

- a general malfunctioning of the Inner Bay aquatic ecosystem due to the above disruptions.

The causes of these biological problems are basically:

- high inflows of nutrients from untreated and partially treated domestic waste waters;

- high inflows of nutrients from storm waters entering the Inner Bay;

- high inflows of sediments and suspended materials from both of the above sources.

There is no reason to believe that the Inner Puno Bay is now at some stage of biological equilibrium with its environment. The expectation is that if the causes of the biological problems are not effectively dealt with, the Inner Bay ecosystem will continue to decline as it has done for so many years.

6 PUBLIC HEALTH CONDITIONS

6.1 SURVEY

Faecal and coliform bacteria were found in large numbers by Rivera *et al* (1989) in the waters of Inner Puno Bay in the early 1980s. Faecal coliforms occurred in numbers of up to 10^5/100 ml, with numbers being highest at the western end of the Inner Bay along the Puno waterfront close to major sewage and run-off discharges. Numbers decreased to zero by the centre of the bay, some 2000 m from the shore. Ocola and Torres (1997) found similar numbers (1.4×10^4 - $22.5\ 10^4$) of both total and faecal coliforms along the western seafront and at Espinar Island close to the discharge point from the treatment lagoon.

Sanchez *et al* (1989) found the eggs of a variety of intestinal parasites in the waters of the Inner Bay, particularly close to the western shores. These included the helminth parasites *Trichuris* sp, *Ascaris* sp, *Hymenolepis nana, Taenia* sp and *Ligula intestinalis*. A survey amongst people living close to the shore in Puno Bay showed that 14% were infected by one or more helminth, with rates up to 40% for young people. Helminths are spread by ingesting their eggs or other developmental stages from contaminated water and food as well as from hands of infected people soiled by faecal matter.

The presence of bacteria and helminth eggs in the Inner Puno Bay show that it is not suitable for any water contact activities e.g. swimming, washing clothes, fishing. The water has a high risk of infection from any of the numerous pathogenic organisms (bacteria, viruses, protozoa, helminths) that can be transmitted via water and occur there because of inputs of untreated and partially treated waste waters. Additionally, the inundation zone of Inner Puno Bay is used extensively as a public open latrine and is a major potential source of disease.

In the middle 1990s there was a cholera outbreak in Puno. Its spread was believed due at least in part to eating cholera-contaminated fish from the Inner Bay, the pathogen arriving in the first place from improperly treated sewage or from the inundation zone.

None of the organisms referred to above have been found in the Outer Puno Bay.

6.2 PUBLIC HEALTH PROBLEMS

The waters of the Inner Puno Bay are a major health problem. Pathogenic organisms are particularly abundant around the shore, especially close to the waterfront. The problems are caused by discharges of untreated and partially treated domestic waste waters and rainfall run-off, as well as the use of the inundation zone as a public latrine by many people in Puno.

CHAPTER – IV

FRAMEWORK OF THE INTEGRATED WATER POLLUTION CONTROL PLAN FOR PUNO INTERIOR BAY

CHAPTER – IV

FRAMEWORK OF THE INTEGRATED WATER POLLUTION CONTROL PLAN FOR PUNO INTERIOR BAY

1. CONCEPT OF THE INTEGRATED WATER POLLUTION CONTROL PLAN

1.1 GOAL

(WHAT IS THE GOAL OF THE PLAN ?)

The Integrated Water Pollution Control Plan aims primarily to improve the water quality of Puno Interior Bay polluted by urbanization of Puno City, and consequently to contribute to the conservation of its unique natural environment and to the development of the regional economy and living conditions.

1.2 SUBJECTS

(WHAT ENVIRONMENTAL FACTORS SHOULD BE CONSERVED ?)

- Water Quality of Puno Interior Bay
- Scenery of Puno Interior Bay
- Flora and Fauna of Puno Interior Bay
- Public Health Conditions of Puno Interior Bay and Puno City

1.3 PURPOSE

(WHY THE WATER POLLUTION OF PUNO INTERIOR BAY SHOULD BE CONTROLLED ?)

(1) Solution of the Water Quality Problems of Puno Interior Bay

- Recovery of the lake water transparency
- Control of the bacterial contamination
- Control of *Lemna* outbreak

(2) Protection of Puno Exterior Bay from Expansion of Water Quality Problems in the Interior Bay

- Control of the intake water quality for water supply
- Control of the water quality for fishery

(3) Conservation of the Natural Environment as a Tourist Attraction

- Improvement of the Scenery
- Conservation of the lake water ecosystem (Totora, wild birds, etc.)

2. STRATEGY OF THE PLAN

2.1 TARGETS

(WHAT LEVEL SHOULD BE REACHED ?)

(1) Lake Water Quality

Recovery of the acceptable water quality as it used to be in the 1970's

(2) Scenery

- Reduction of *Lemna* distribution
- Reduction of littered solid wastes to an insignificant level

(3) Ecosystem

- Rehabilitation of reed (Totora) belt
- Conservation of habitats for wild birds
- Recovery of fish and benthos

(4) Public Health Conditions

- Reduction of littered wastes in the watershed and the lake
- No bacterial contamination in the watershed and the lake

2.2 TARGET YEAR

(BY WHEN WILL THE PLAN MATERIALIZE ?)

Short-term target year : the year 2008
Mid-term target year : the year 2015
Long-term target year : the year 2025

2.3 TARGET AREAS

(WHERE WILL THE PLAN TARGET ?)

(1) Measures against the Water Quality Problems

1) Watershed / Catchment Area

The whole catchment area of Puno Interior Bay

2) In-Lake

Puno Interior Bay

(2) Measures against the Deterioration of Scenery

The whole Puno Interior Bay and its Hinterland

(3) Measures against the Ecological Problems

Northern, western and southern shores of Puno Interior Bay

(4) Measures against the Public Health Problems

The whole catchment area and the littoral area of Puno Interior Bay

2.4 METHODOLOGY

(HOW TO CONTROL THE PROBLEMS ?)

In general, possible efforts to improve lake environment are classified into the following three categories:

- Structural Measures
- Non-structural Measures
- Environmental Monitoring

Structural measures are defined as the measures taken by administrative bodies to physically improve the environment of Lake Titicaca. Non-structural measures are defined as the measures which aim to motivate the state/local governments, private sectors or citizens to take some actions for environmental improvement. Environmental monitoring is defined as an environmental administration tool which detects/identifies environmental problems, assesses the effects/impacts caused by the implementation of structural measures, and rouses people's awareness. Although the structural measures must be main category, the integrated plan will not fulfill its function unless all measures are systematically combined. The conceptual figure of "The Integrated Water Pollution Control Plan for Puno Interior Bay" is shown in *Figure IV.2.1*.

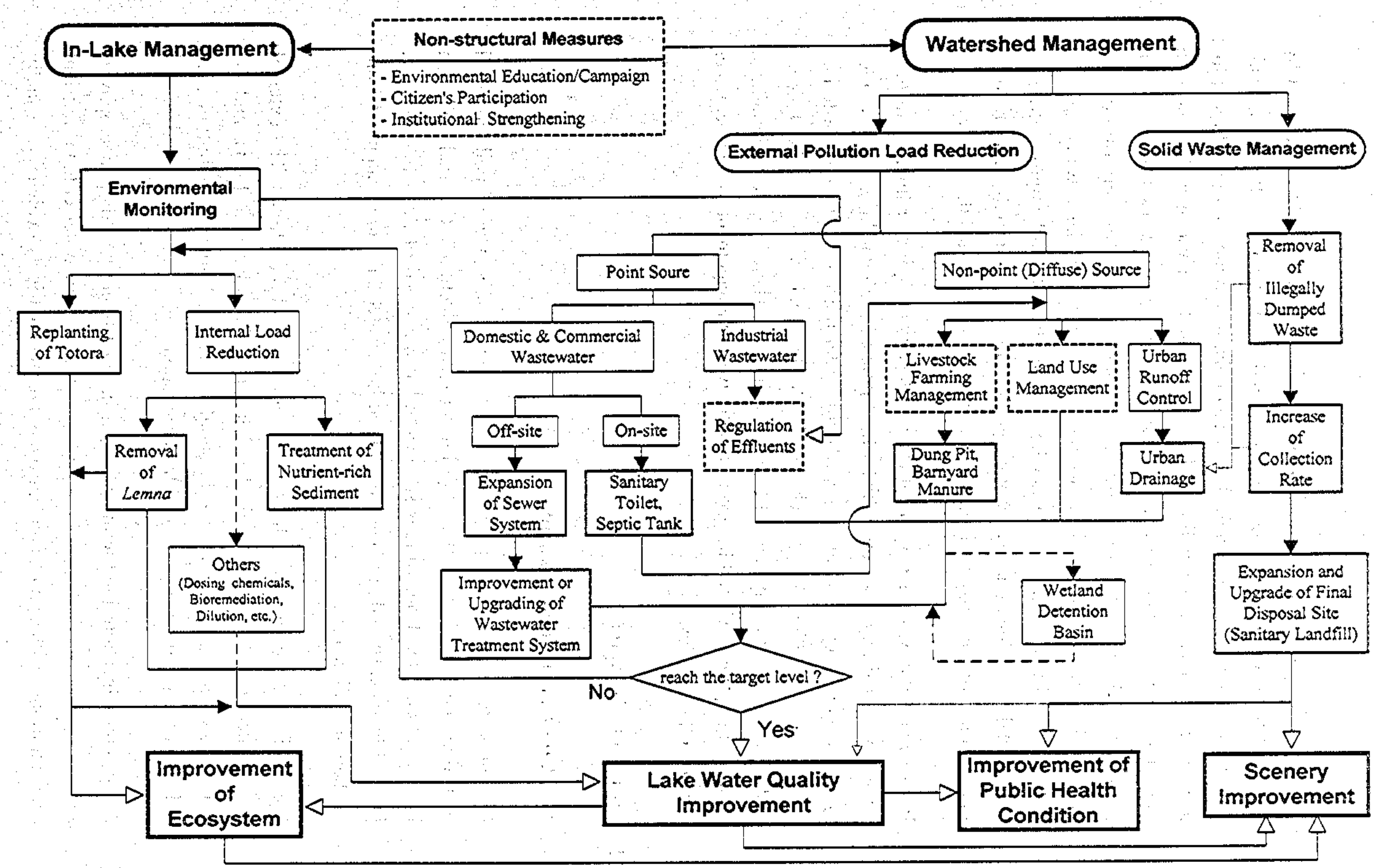


Figure IV.2.1 Conceptual Figure of The Integrated Water Pollution Control Plan for Puno Interior Bay

Water quality problems of Puno Interior Bay have been undoubtedly caused by pollution loads discharged from Puno City and the watershed. Pollution loads have been accumulated in both the lake water column and the bottom sediment for a long time. Lake water pollution has deteriorated ecosystem and scenery in Puno Interior Bay. Poor wastewater management has also caused public health problems such as waterborne diseases. Therefore the first priority of the integrated plan should be given to the improvement of lake water quality. Pollution load reduction in the watershed and in the lake will improve the lake water quality. Consequently, water quality improvement will contribute to improvement of the ecosystem, the public health conditions, and the scenery.

Insufficient solid waste management causes illegally dumping or littered waste in the drainage and on the streets, which affect public health conditions or sewerage systems and clog up urban drainage. Storm water flushes the littered waste into the lake or inundation area, which deteriorate the scenic view of Lake Titicaca that is an important component of tourist atractions. Therefore, in the integrated plan, a high priority should be given to solid waste management as well as water quality improvement.

(1) Structural Measures

1) Water Quality Improvement

Measures are broadly classified into two categories; one is external pollution load reduction and the other is internal pollution load reduction. External pollution loads are generated from various sources in the watershed of Puno Interior Bay. Internal loads exist and are generated in the lake water column or supplied from the bottom sediment.

Measures should be begun with external pollution load reduction. The external load reduction should begin with the reduction of point source loads, and the reduction of non-point source loads should follow it. Internal pollution load reduction should follow the external load reduction.

As for eutrophication, long term reduction in algal biomass and/or macrophytes such as *Lemna* usually requires a significant reduction in water column nutrient concentrations. Phosphorus or nitrogen are the nutrients which are usually targeted in lake management because they are often the nutrients in shortest supply relative to plant demands and they thus can limit further macrophytes or algal growth.

a. External Pollution Load Reduction

In Puno City, domestic and commercial wastewater are major point sources of pollution loads. The most of them can be collected by sewer system, treated by wastewater treatment system, and finally discharged to the lake as effluents of wastewater treatment plants. Therefore the first priority of external pollution load reduction should be given to sewerage system development.

In the sewerage non-served area, domestic and commercial wastewater should be treated on the site by a sanitary toilet or a septic tank before discharging into streams, drains, groundwater, or directly into the lake. There are few major industrial pollution sources in Puno City, however major pollution sources such as slaughterhouse should be enforced to install a wastewater treatment facility at their own expenses by the effluents control regulation.

Nonpoint (diffuse) pollutant loading to streams or directly to the lake is loading which does not enter from sources such as pipes but instead from overland flow or groundwater seepage. Agricultural and urban areas are important nonpoint sources and are difficult and expensive to control intensively or effectively by structural measures.

b. Internal Pollution Load Reduction

A significant reduction in external pollution load is an essential, but not necessarily sufficient step towards the lake water quality improvement for long term control of eutrophication. Internal nutrient loading from aerobic and anaerobic sediments, from groundwater seepage, from decomposing macrophytes, and from organism activities, can add nutrients to the water column at rates equal to or greater than external loading. External nutrients reduction may not have all of the expected effects of lowering macrophytes or algal biomass until these internal sources are managed.

Possible measures should be divided into two categories, one is to directly decrease pollutants' concentrations in the water column and the other is to reduce pollutants' loading from the bottom sediment

More than one technique may be used at once. Nevertheless, for most in-lake techniques to be effective, important external loading sources should be controlled first.

2) Scenery Improvement

In the watershed, littered wastes in the streams, along the shoreline, on the streets or around the final disposal site deteriorate the scenic view of Lake Titicaca. Therefore solid waste management is an urgent measure for scenery improvement in the watershed.

In the lake, nuisance spread of *Lemna* deteriorates the scenic view. Therefore the removal of *Lemna* must be urgent, but the monitoring is indispensable to check unexpected negative impacts such as outbreak of algae which may take *Lemna*'s place. Totora (reed) is the main component of the scenery of Lake Titicaca, and so replanting of Totora would recover the lost natural view.

3) Ecosystem Improvement

Water pollution has caused poor aquatic ecosystem in Puno Interior Bay. Therefore the aquatic ecosystem will not be improved until the lake water quality is improved.

According to the result of this Study, aquatic ecosystem is rich around Totora bush/belt, and richer than in both Puno Exterior Bay and main lake. Totora bush/belt seems to provide an excellent water environment for plankton, benthos and fish. Furthermore it provides a habitat or nesting place for wild birds. Abundance of wild birds is also an excellent component of tourist attractions. Therefore the replanting of Totora will recover or enhance the ecological potential in Puno Interior Bay.

4) Public Health Condition Improvement

Insufficient waste collection system is main problem of solid waste management in Puno City, which causes illegally dumping and littered solid wastes. Removal of illegally dumped and littered wastes is a direct measure against public health problems caused by littered wastes, but not an essential way. The most essential and urgent measure should be an increase of waste collection rate. Furthermore a final disposal site should be expanded in parallel with an increase of collection rate. However the existing final disposal site is operated by open-dumping way, and so dumped wastes are littered, contaminated water leaches out and flys breed around the site. Sanitary landfill system should be applied to a new final disposal site according to the guideline proposed by the Ministry of Health.

It is often seen in Puno City that some citizens use the lakeshore as an open-air latrine or sewage overflows after a heavy rainfall. It must cause bacterial contamination in the littoral area of Puno Interior Bay. To solve this public health problem, the sewerage system should be improved or expanded at the highest priority, and the spread of sanitary toilet or septic tank should be encouraged.

(2) Non-structural Measures

Non-structural measures should support or supplement structural measures. A large scale investment will be necessary for some structural measures such as expansion of sewerage systems. To raise the project funds, it will be necessary to raise the water charge rate. In such cases, citizen's understanding and consensus for the projects should be formulated through environmental education or campaign. To reduce the project cost or to make the project smoothly, it will be necessary to request citizen's voluntary participation. To execute or manage the project effectively, relevant organizations or systems should be effectively strengthened or consolidated.

Industrial wastewater should be controlled by effluent regulation. It is difficult to effectively control non-point sources with a reasonable cost by structural measures, and an appropriate land use should be encouraged to minimize non-point source pollution loads. Because livestock farming seems to generate a great deal of non-point source pollution loads, it should be regulated to use the area close to the lake

(3) Environmental Monitoring

Periodical and continuous environmental monitoring should be urgently practiced as a decision-making toll, in order to identify the environmental problems and the measures against the problems, and to monitor the expected effects or the unexpected impacts by the structural measures. Especially, eutrophication is caused by sensitive aquatic ecosystem. Change of nutrient balance may cause new eutrophic problems other than the outbreak of *Lemna*. Monitoring of pollution sources will bring rational bases to regulate the effluents.

2.5 MANAGEMENT AND EXECUTION OF THE PLAN

(WHO WILL BE RESPONSIBLE FOR IMPLEMENTATION OF THE PLAN ?)

(1) Overall Management

State level authorities who is competent to coordinate several sectorial organizations, to decide on a policy, to raise funds, to control budget and to supervise the whole project

(2) Execution of Subprojects

Sectorial organizations who have experiences in each field and capacities to execute subprojects

(3) Citizen's Participation

Puno Provincial Municipality or multi-sectorial organization(s) who is composed of representatives of the interested parties, can organize resident's campaigns for environmental improvement and can encourage public/private sectors to assist the campaigns voluntarily.