Polluted fish landing sire in the Royapuram fishing harbour, Modras.

Tamil Nadu and Pondicherry, Indian East Coast

by

I. Joseph A. Jerald

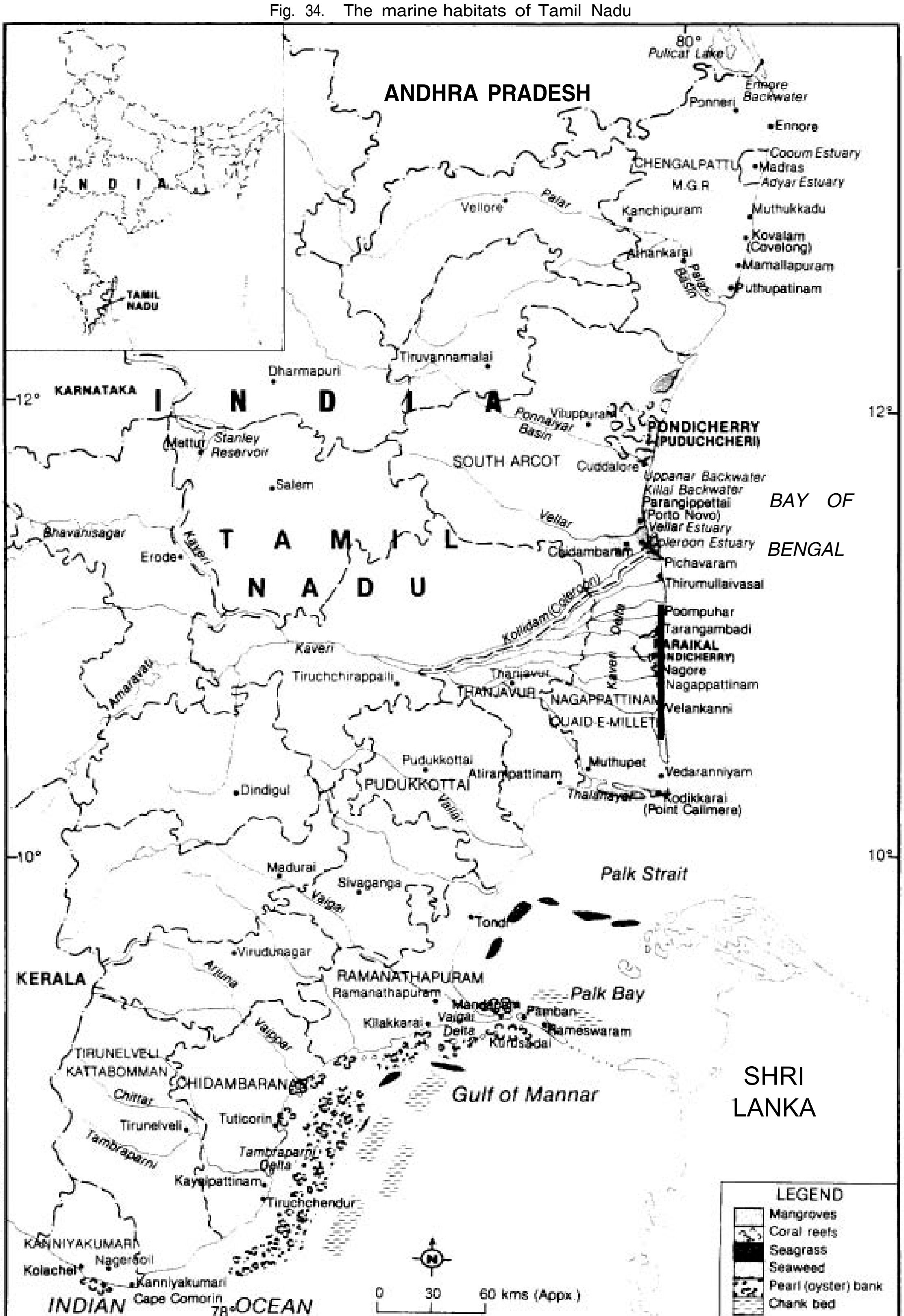
Consultant-Environment/BOBP

51. *MARINE HABITATS*

51.1 *Mangroves*

Mangroves flourish in the Pennar and Kaveri deltas of Tamil Nadu as well as further south in the Tuticorin and Rameswaram areas. Productive forests are found at Pichavaram and Kodikkarai (Point Calimere) (Muthupet, Chatram, Puthupatinam and Talanayar) (see Figure 34).

Fig. 34. The marine habitats of Tamil Nadu



Cartography TT. Maps. Madras-44

The lush mangroves forests are protected by the Forest Department as Reserve Forests. The total area under mangroves in Tamil Nadu is about 225 km^2, about 3 per cent of India's mangrove forest area.

One of the largest and most unspoiled mangrove forests in Tamil Nadu is in Pichavaram in South Arcot District. This forest has 110 km^2 of mangroves, including 14 km^2 that is deemed Reserve Forest. This forest is spread over 51 islets separated by a complex network of creeks and channels (Nagarajan, 1990). A long sand bar separates the whole area from the open sea. The Kollidam (Coleroon) River, emptying into the south end of the lagoon, provides the bulk of the fresh water and sediments inflow. But since this river is used for irrigation, it deprives the mangroves of freshwater supply at critical stages. This results in salinity increase.

Most of the other mangroves in Tamil Nadu have been degraded and are close to extinction. In a few areas, the coastline is fringed by Cusuarina *aquisetifolia* and dune vegetation.

5 1.2. *Coral reefs*

Coral formation in Tamil Nadu is mainly confined to the Gulf of Mannar and Palk Bay. Some patchy growth is also found at Enayam, on the west coast of Kanniyakumari District (see Figure 34 on p. 185). A Marine National Park has been established off both sides of the Mandapam Peninsula along the southern coast of Tamil Nadu, to protect the coral reefs in the Gulf of Mannar and Palk Bay that are facing severe ecological threats.

The Gulf of Mannar reefs extend from the Rameswaram archipelago to Tuticorin in a NE-SW direction over a distance of 140 km. The formation is estimated to be 100 km^2 in extent (Wafar, 1986). The reefs are discontinuous and are mainly found around twenty small islands, at a maximum depth of about six metres (Wells, 1988). These are small fringing reefs, built on the shallow shores of islands that were separated from the mainland in the past by wide subsidence.

The reefs of the Palk Bay, about 30 km in length, stretch in an east-west direction along the Mandapam Peninsula and the shore of Rameswaram island. They are found 200-600 m from the shore in broken patches.

The outer side of the reef harbours ramose corals, while the inner side has massive corals with large polyps. Sedimentation on the shoreward side influences the distribution of corals. The reefs were once mined and, in 1964, were subjected to a cyclonic tidal wave which killed and uprooted many ramose corals. Recolonisation is presently underway, albeit slowly, since the reef is not flourishing.

Pillai (1971) has pointed out that the inshore waters of the Palk Bay become very turbid during the Northeast Monsoon, due to sedimentation. This causes mortality to the coral colonies on the inner side of the reef, where only the species with large polyps survive.

Ninetyfour species, belonging to 37 genera, have been recorded in the Gulf of Mannar and the Palk Bay (Pillai, 1971). The notable feature of the coral in this area is that many common genera found in other parts of the lndo-Pacific are **not** found here. The genera *Pocillopora, Arcopora, Montipora, Porites* and *Leptastrea* are the commonest here. The species of the genera *Montipora* and *Arcopora* have a well-diversified propagation, while Favia spp. and *Favites* spp. are moderately fertile.

Scleractinian corals contain calcium carbonate, which is the raw material for many industries. Corals have been used in Tamil Nadu from earliest times in the preparation of lime and mortar for house building. The establishment of a calcium carbide factory in Tirunelveli District (south Tamil Nadu) paved the way for large-scale quarrying of coral from this area. In the late Sixties, it was estimated that about 500 people were engaged in the Mandapam area collecting coral. It has been reported that 250-300 m^3 of reef was brought ashore daily (Pillai, 1973). According to Venkataramanujam *et* al. (1981), nearly 15,000 t of coral are annually removed from the reefs around Tuticorin, in addition to about 10,000 t of dead shingle *(challi)* washed ashore. Thomas and George (1987) have reported that intensive removal of corals near Tuticorin and in the Gulf of Mannar have greatly reduced the productive coral habitats of Tamil Nadu. Exploitation of corals have totally destroyed reefs in many sites and their recolonization is a remote possibility, since no reef framework is left, as in the case in Manauli Island off Mandapam. Studies of Mandapam reef in the Palk Bay have, however, shown that the fast growing genus, ***Acropora,*** could establish itself on hard rocks. This appears to make reasonable recolonization possible in 10-15 years.

Any plan of action on coral conservation and reef resources should emphasize the necessity of limiting man-made reef destruction. If no action is taken soon, one of the most valuable and useful marine resources of Tamil Nadu will be completely exterminated (Thomas and George, 1987). Fortunately, there is increasing concern in the state for reef protection.

Concrete well rings, with coconut fronds, are being used as fish aggregating devices by some fisherfolk villages 20 to 25 kms south of Madras. These artificial reefs become encrusted with heavy growth of algal mats, barnacles, green mussels and other bivalves, tubicular polychaetes and bryozoans and become something like 'submarine gardens or parks' in areas where such natural ecosystems have been destroyed by continuous bottom-trawling. These artificial reefs also help to rehabilitate fish that have been denied natural breeding sites in coastal waters due to various pollution hazards.

5 1.3 Seagram beds and seaweeds

SEAGRASS

Little information is available on the extent of seagrass beds along the Tamil Nadu coast.

Studies of the environmental impacts on seagrass beds in the Gulf of Mannar have been made by Rajeswari and Kamala (1987). They reported six genera and eleven species.

Recent studies, indicate that the islands in the Gulf of Mannar are extremely rich in seagrass (see Figure 34 on p. 185). Salm (1975), however, has claimed that there used to be large seagrass beds in the Gulf of Mannar, which supported large dugong (seacow) herds that have now almost entirely disappeared. He adds that the most extensive areas of seagrass beds are, possibly, in the Palk Straits.

Twelve seagrass species are found in this region: ***Halodule uninervis, H. pinifolia, Cymodocea rotundata, C. serrulata, C. syringodium, C. isoetifolium, Enhalus acoroides, Thalassia hemprichii, Halophila ovalis, H. ovata, H. decipiens, H. stipulacea,*** and ***H. becarii.*** This includes two new records, namely ***Halophila decipiens*** and ***H. becarii.***

Although no estimates have been made for the South Asian seas, estimates elsewhere suggest that the economic value to be obtained from seagrass beds can reach approximately $ 3,500 per ha (Thorhaug, 1983).

Partly because of the relatively inconspicuous nature of this habitat, impacts on seagrass beds have been much less well-documented than have those of other major marine ecosystems. Very little, in fact, is known about the environmental status of the seagrass beds. It is nevertheless possible that eutrophication and sedimentation have caused damage, since seagrasses are extremely sensitive to reduced light penetration.

Aside from this, mechanical substrate turbulence is the most disturbance caused by humans to seagrass beds.

The Indian Marine Biological Association has emphasised the need for seagrass bed protection, to which little attention has been paid in the past. Coastal activities, such as boat construction, human settlement and wastewater disposal should be prohibited in the vicinity of seagrass beds, it has been recommended.

SEAWEED

The economic importance of seaweeds in this region, their mode of exploitation, research on various aspects of their culture, as well as uses, are still in an explorative stage (Krishnamurthy, 1991). Nevertheless, seaweed has been exploited along the Tamil Nadu coast since 1952. It has been reported that the coastal seaweed resources have been diminishing over the years, and conservation, particularly of *Gelidiella acerosa,* has been advocated. Krishnamurthy (1986) has stated that, as yet, no successful effort at large-scale seaweed cultivation has been undertaken off Tamil Nadu coast.

Estimated standing seaweed stocks are listed alongside.

Seaweeds of the Tamil Nadu coast (estimated standing crop)

Flora	*Wet weight (t)*
Agrophytes	
Gelidiella acerosa	*74*
Gracilaria edulis	*345*
Gracilaria spp.	*629*
Carrangeenophy tes	
Hypnea must informes	*293*
Hypnea spp	505
Alginophytes	
Sargassum spp	9381
Turbinaria spp	740

Source: Survey of 1971-75

52. MARINE FAUNA

52.1 Fisheries

Tamil Nadu has a coastal fisherfolk population of 470,000, who form almost one per cent of the state's total population. The state has one major fishing harbour, Madras, and one minor one, Tuticorin. These are landing centres with berth facilities at Mallipatnam, Kodikkarai (Point Calimere), Cuddalore and Rameswaram. However, localized small-scale fishing activities are prevalent all along the coast.

Tamil Nadu has 4000 mechanized vessels (1986), more than 80 per cent of which are of 30-32-feet length, resulting in crowding at 0- 30 fathom depth range. The state is fourth in marine production in India. The annual production during 1990-91 was 289,000 t, accounting for 17 per cent of the country's total marine production (Department of Fisheries, Government of Tamil Nadu).

The exploitation of inshore species in Tamil Nadu is primarily artisanal or small-scale, utilizing a wide range of gear types and craft.

An acoustic survey, both off Cape Comorin and in the Gulf of Mannar, gives an estimated average standing stock of 624,000 t, composed mainly of pelagic species. Of this, the *Stolephorus* (Anchovies) stock was estimated to be 82 per cent.

Among the coastal pelagic resources, the Clupeoids, Scombroids and Carangids are the dominant groups in Tamil Nadu. In the Clupeoids group, *Sardinella* and ***Stolephorus*** are the major species and among the Scombroids, *Rastrelliger* are significant. Tuna and tuna-like fish, as well as the Spanish Mackerel, are the most exploited fish in Tamil Nadu. Tuna catches show highly seasonal fluctuations; peak catches of both Little Eastern and Frigate Tuna are recorded in July-September (Skillman 1982).

52.2 Aquaculture

Shrimp farming is the dominant aquaculture practice in Tamil Nadu. Of the 56,000 ha of estimated brackishwater area in the state, about 176 ha are currently under culture, and a production of over 88 t of shrimp has been reached. The Government has identified 15,000 ha more for brackishwater culture.

Many private firms have recently gone into aquaculture and have touched yields of up to 500-2000 kg/ha/crop. Smaller farmers have usually achieved 500 kg/ha/crop in 4-5 month culture periods.

In the coastal villages of South Arcot and Quaid-e-Milleth Districts, several shrimp farms have been started by private sector concerns. Some of these projects have lacked ecological planning and have destroyed mangrove forests and swampy lagoons during indiscriminate pond construction.

5 2.3 Molluscs

The pearl banks and chank beds off Tuticorin in the Gulf of Mannar (see Figure 34 on p. 185) have been renowned from the earliest times (Rajendran et *al.* 1988). The prevailing two monsoons and other climatic conditions, together with the hydrological situation in the Gulf, have favoured production of pearl oysters and chanks. The traditional pearl fishery continued till the early Eighties, when the banks were found to be exhausted. The Central Marine Fisheries Research Institute (CMFRI), in an attempt to tackle the problem, has launched a pearl culture project. Techniques for the production of a free and spherical cultured pearl oyster, ***Pinctada fucata,*** were developed in India in 1973. A multiple nuclei implantation technique and reuse of the oysters for a second crop have further improved production rates. Tamil Nadu Pearls Limited, with a laboratory for nucleus implantation at Mandapam and another for collection of oysters at Tuticorin, started a farm at Kurusadai Island.

Tuticorin, once called 'The Pearl City', has been rapidly industrialized during the last two decades. Since then, pearl production has diminished substantially. The sacred chank, Xancus pyrum, found since ancient times, has also become very scarce. Apart from industrial pollution, silt and mud carried by the Tambraparni River have been detrimental to the natural habitats of pearls and chanks in this Gulf.

Oysters and clams are distributed in estuaries, backwaters and bays along the coast. They are highly nutritious and provide a cheap protein source for the rural coastal population. These shellfish are collected during low tides and are a subsistence fishery.

Several species of oysters flourish along the Tamil Nadu coast. Among them, the backwater oyster, ***Crassostrea madrasensis,*** dominates. C. *crista galli* and the rock oyster, ***Saccostrea cucullata,*** also occur, albeit in smaller quantities. The commercially important clams are ***Meretrix meretrix, M. casta, Katelysia opima*** and ***Anadara rhombea.***

Available information on the standing stock of oysters (mostly C. ***madrasensis)*** is summarized below.

Oyster resources of the Tamil Nadu coast

Area	Extent of bed in ha	Shell on biomass (t)	Reference
Pulicat Lake	9	1321	Thangavelu & Sanjeevaraj (1988)
Ennore	45	18616	Sarvesan et *al. (1988)*
Muttukkadu backwaters	4	5450	d o
Athankarai	14	389	Rao et al., (1987)
Thirumullaivasal	25	75	Muthiah & C T Rajan (pers communication)
Tarangambadi (Tranquebar)	0.6	26	d o
Nagore	0.5	3	d o
Karangod	0.5	40	d o
Muthupet	1500	16740	M.E. Rajapandian (pers communication)
Total	1598.6	42660	

Bivalve wild stocks are vulnerable to overfishing. In order to overcome this situation, techniques for farming C. ***madrasensis*** have been developed at the Tuticorin Research Centre of CMFRI (Nayar, 1987). Technology for mass production of oyster spat has also been developed by the CMFRI at Tuticorin (Nayar et ***al.,*** 1988). The Centre has, in addition, developed a hatchery technology suitable for mass production of clam seeds.

53. FZSH KILLS

Mortality of fish and aquatic organisms due to pollution has been observed in the inshore waters of Kayalpatnam, 30 km south of Tuticorin, as well as in adjacent areas, since the early Eighties. The lagoons in this area extend a distance of three km before joining the sea. The lagoon mouth remains closed for most of the year, except during the peak of the Northeast Monsoon, when it opens, discharging the polluted water into the sea.

Two major chemical works at Shahupuram, near Kayalpatnam, are the main polluters. Pollutants from them include organic compounds, chlorinated hydrocarbons and mercury. The sudden release of polluted water when the lagoon mouth opens, usually in November, is believed to be the cause of the mass mortality of fish and aquatic organisms in inshore waters (Kasim et *al.,* 1991). The duration of such kills is, however, only a day or two.

Fish kills have also occurred at nearby Tiruchendur. Most of the dead organisms were found close to the lagoon by one of the chemical works, they were less towards Tiruchendur town. About twenty different groups of marine organisms, comprising fish, crab, starfish, molluscs and others, were found affected by the polluted water. Most severely affected were mullets, catfish and eels. Chemical analyses of the water revealed that the pH was less than 3.5 near the lagoon.

Similar instances of fish kills have been reported in the Kaveri riverine stretch near Mettur in Tamil Nadu. Effluents from chemical industries here were attributed as the cause for mass fish and aquatic organism mortality.

Phytoplankton blooms have been reported in the Pamban area near the Kurusadai Islands in the Gulf of Mannar since the early Forties. They have caused mass mortality of marine organisms. Studies have been carried out on the ***Trichodesmium erythaeum*** bloom in the waters around the Kurusadai islands. In September 1972, were the occurrence of a bloom that lasted for seven days, over an area of about 7 km^2, was recorded. There was, however, unlike in previous cases, no mortality of fish or other organisms. The phosphate content decreased with the advance of the bloom and, finally, disappeared during the last days of bloom proliferation. Nitrate was not traceable. Phosphate loss and lack of its replenishment might have acted as a deterrent to the bloom flourishing.

In 1970, Porto Novo waters experienced the ***T. erythaeum*** bloom.

Studies on microbial pollution in Tamil Nadu's coastal waters have been carried out in a few universities. In recent years, fish and shellfish from coastal areas have been blacklisted as notorious transmitters of food-borne diseases, and there are reports of fish infection by bacteria in Tamil Nadu. A survey conducted near the Parangipettai (Porto Novo) coast recorded several instances of fin rot diseases (Lakshmanaperumalsamy ***et al.,*** 1984). Occurrence of bone tumour (in a catfish, ***Tachysurus*** spp.), fin necrosis accompanied by external haemorrhage, ulceration and loss of scales symptoms were also quite common due to bacterial infections.

54. MARINE POLLUTZON

54.1 Domestic wastes

Domestic wastes from many coastal cities in Tamil Nadu are directly discharged into the coastal waters (see table on facing page, top) while in others they are carried to the sea through waterways such as rivers, streams and other freshwater systems.

Sewage production and BOD load from coastal towns in Tamil Nadu

Name of lown	Status	Population 1981	Sewage production ı 10 l/d	BOD 10 kg day***
1. Madras	Class I	3,276,622	195.0	983
2. Cuddalore	Class I	127.625	7.5	38
3. Tuticorin	Class I	192,949	II.5	57
4. Chidambaram	Class II	55,920	3.4	16
5. Nagapattinam	Class II	82,626	5.0	24
6. Tiruchendur	Class II	24,233	1.5	7.2
7. Rameswaram	Class III	27,928	0.8	8.4
8. Kolachel	Class III	23.124	θ.7	6.9
9. Parangipettai (Porto Novo)	Class III	20.100	0.6	6.0
10. Vedaranyam	Class III	26,573	0.8	7.9
11. Atiramapattinam	Class III	21,179	0.7	6.3
12. Kilakkarai	Class III	27,842	0.9	8.3
13. Mandapam (Pamban)	Class IV	14,806	0.45	4.4
14. Kanniyakumari	Class IV	14,087	0.45	4.4
15. Tondi	Class IV	11,148	0.35	3 5
16. Ponneri	Class IV	16,021	0.50	4.8
17. Tarangambadi (Tranquebar)	Class IV	18,607	0.55	5.5
18. Thirumullaivasal	Class IV	10,326	0.30	3.1

* at the rate of 60 l/day for Class I & II and 30 l/day for Class III & IV cities

** at the rate of 0.3 kg/day person

The major cities situated on the coast are Madras, Cuddalore, Pondicherry and Tuticorin. More than 500 fishing villages and small towns are also found there. The estimated population of these coastal cities stands at roughly six million. The domestic wastes discharged into the sea from the urban and rural areas are untreated. In Madras City alone, there are more than three million people living on the coast. Much sewage is washed into the Cooum and Adyar rivers and the Buckingham Canal in Madras city. The standards set (7968 of 1976) by the Indian Standards Institute (ISI) for different pollutants in the effluents discharged into the sea are presented in the table below together with, as a comparison, the values recorded from the waters of the River Cooum, at the discharge points by Napier Bridge. The data clearly shows the high pollutant load being added to coastal waters. Sewage pollution is more severe in Madras compared to other places (Ramachandran, 1990).

Effluent water quality (UNEP, Ecology 2(8):13)

Pollution parameters	ISI Standard	Minimum national standard proposed	Reference efflument*	River Cooum
TSS (mg/l)	100	20	30	6343**
Oil grease (mg/l)	20	10	1.4	–
BOD_5 (mg/l)	100	15	30	176**
COD (mg/l)	250	NS	6.2	351**
Phenols (mg/l)	5	I	–	10**
Sulphide (mg/l)	5	I	–	120***
pH	5.5-9	6-8.5	7	7.3'

Source : * Srandard proposed by UNEP

** Somasundaram et al., (1987)

*** Rarichandran (1987)

According to Ramasubramaniyan et *al.* (1991), the pollution in the Madras coastal waters is mainly due to sewage inflow into the Cooum River.

There are several reports available on the distribution of human pathogens, bacteria water indicators as well as sediment, phytoplankton and fauna1 samples along the Tamil Nadu coast. The seasonal incidence of *Escherichia coli* in environmental samples (water, plankton and sediments) in 1981-82, and in sea foods in 1982-83, were monitored at the Vellar estuarine region in Parangipettai (Natarajan and Ramesh, 1987). High *E. coli* counts in water (1.7 x 10^3/100 ml), plankton (3.6 x 10^4/g) and sediments (7.0 x 10^3/g), were recorded during monsoon and post-monsoon periods, while low values were recorded during the summer.

The incidence of three new serotypes of *Salmonella, viz. S. irumu, S. Panama* and S. *lexington,* was recorded for the first time in India in environmental samples taken in the Pichavaram mangroves and in the Vellar estuary (Ramamurthy *et al., 1985).*

Sewage sludge has caused extensive contamination of the Vellar estuarine water by enteropathogenic gram negative, motile *E. coli* bacterium and faecal coliform. Water, sediments, plankton, finfish and shellfish in the different zones of the estuary were also affected (Sivakumar *et al.,* 1986). The contamination is reported to have caused gastroenteritis and urinary infection, particularly in children. The presence of the faecal coliforms in aquatic systems, fishing products (see table below) and other sources in this area is considered an index of poor sanitary quality as well as an indicator of pollution.

Incidence of total coliform and faecal coliform associated with a few marine organisms

Collection area in Parangipettai	Group examined	No. of specimens examined	No. and per cent of samples positive			
			Total (No.)	Coliform (%)	Faecal (No.)	Coliform 1%)
Vellar estuary	Fish	62	58	93.55	30	48.39
	Shrimp	12	12	100	10	83.33
	Crab	6	3	50	3	50
	Molluses	14	14	100	8	57.14
	Total	94	87	92.55	51	57.45
Landing site	Fish	50	50	100	40	80
	Shrtmp	50	50	100	44	88
	Crab	24	24	100	16	66.67
	Total	124	124	100	100	80.65

A report on the bacterial flora examination by the State Fisheries Board in the Eighties revealed that the total bacterial count of natural bed oysters ranged from 14.8 x 10^2/g to 11.6 x 10^3/g in the sediment, and the total bacterial count of the surrounding seawater ranged from 4.5 x 10^2/ml to 9.8 x 10^3/ml. Faecal coliforms of natural bed oysters ranged from 0 to 39/100 g in the sediment, and that of natural seawater from 0 to 28/100 ml.

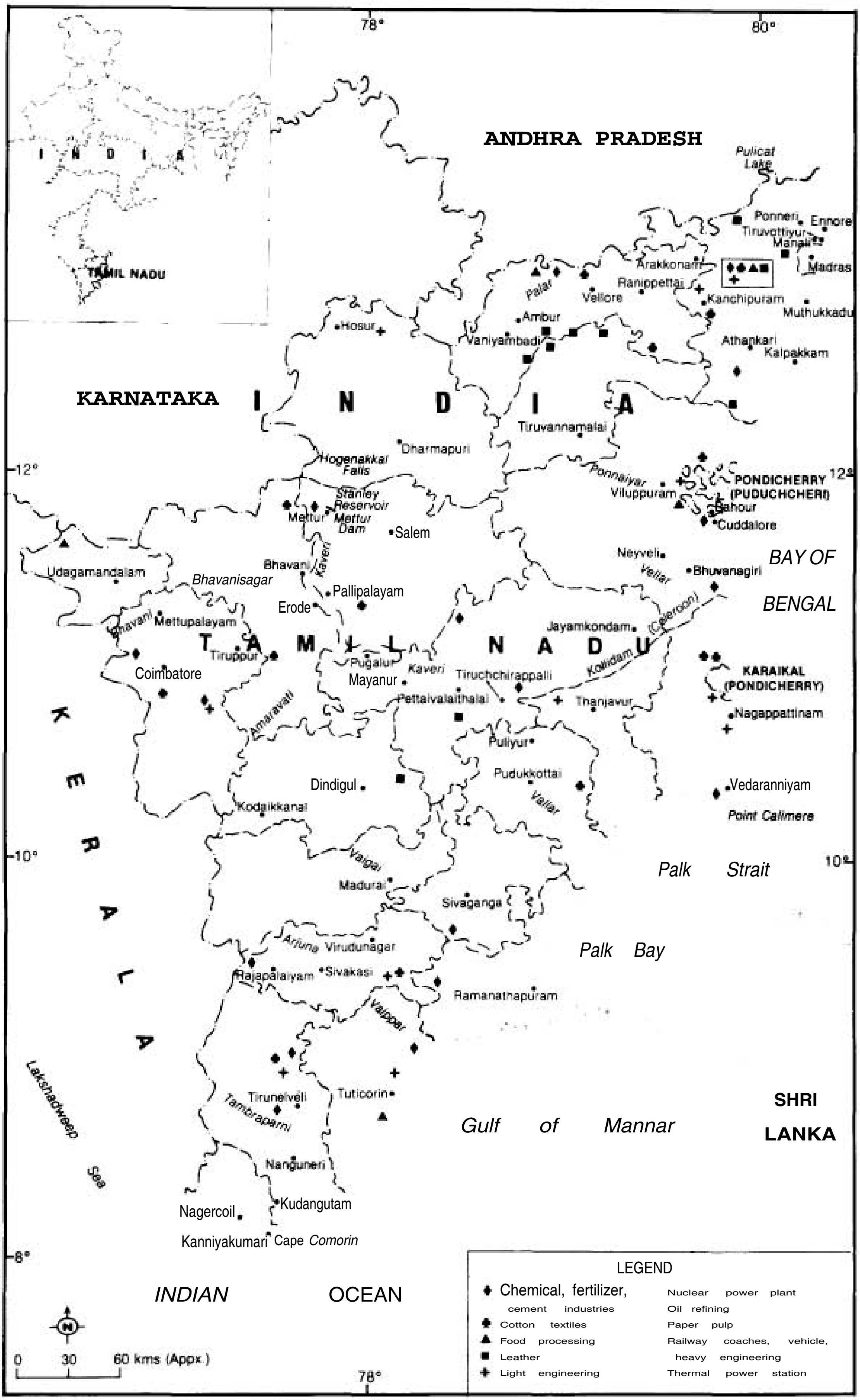
Lakshmanaperumalsamy and Purushothaman (1982) reported heterotrophic bacteria being more abundant with seaweeds than in the seawater. The common genera encountered by them were *Bacillus, Corynebacterium, Vibrio, Alcaligenes and Pseudomonas.* The bacteria present on the surface of *Enteromorpha intestinalis* cells and in the seawater were found to produce the growth hormone Indole acetic acid (IAA) in media supplemented with l- tryptophan (Chandramohan, 1971).

Mycoflora is affected to a very large extent by sewage. Reports on the ecology of higher fungi in marine and brackishwater soils environments are scanty. However, it has been recorded that 86 species of fungi, a majority belonging to fungi imperfecti, and 22 species of marine lignicolus fungi exist. Very recently, Prabhu *et al.* (1991) made a study for two years on mycoflora in seawater and sediments along the Madras coast. Their report identified 26 species of fungi belonging to 14 genera.

54.2 Industries

There are about 12,150 industries in the State of Tamil Nadu and the Union Territory of Pondicherry. Of these, 5650 are situated in the coastal zone and 2500 not far from the coast (see Figure 35 on facing page).

Fig. 35. Map showing the towns, industries and rivers of Tamil Nadu



The major congregation of industries is in Madras. About 1500 industries are located in the city alone. The types of industries in Madras are :

Electricity, gas and water (35%)

Rubber, plastics, petroleum and coal products (9.5%)

Machine tools (9.3%)

Paper and pulp products (5.5%)

Metal products (5.1 %)

Others (35.6%)

Source: (Industrial Profile of Tamil Nadu, 1985) — Department of Statistics, Government of Tamil Nadu).

Quantity of water used in some industries

Industry	*Quantity of water*	*Purpose used*
Thermal power	100- 150 m^3, hr per MW	Cooling
Pulp and paper mills	63-112m^3/t 270m^3/t pulp	Processing of board
Oil refining	350m^3/t crude oil	Processing
Tannery	72m^3/t hides	Processing
Textiles	0.12-0. 19m^3/m 10-20m^3/100 kg goods	Bleaching Dyeing

Major sources of metal pollutants

Pollutant source	*Major Pollutants*
Chlor-alkali factories	Mercury
Industrial coolant water discharge and corrosion of pipelines	Copper
Dust and rain (atmospheric fall-out, petroleum burning)	Lead
Plating and galvanizing (machine tools and metal products)	Zinc, cadmium and chromium
Municipal waste water	Cadmium and copper
Combustion of coal (power plants — flyash)	Copper, lead and zinc
Combustion of oil (power generators)	Nickel
Dredging and dumping of sediments from harbours	Zinc, lead and copper
Antifouling paints	Copper and mercury

HEAVY METALS

Virtually all industrial processes involving water are potential sources of metallic contamination in estuaries and coastal water. The quantity of water used in the various major industries on the coast are given in the table alongside (top). The various sources of metal pollutants and the principal metals associated with these sources are presented in the second table alongside. The heavy metals commonly found in Tamil Nadu coastal waters are cadmium, copper, lead, mercury, nickel and zinc.

The metal levels in the offshore and coastal waters of various regions of Tamil Nadu, as well as concentrations recorded from the Cooum River (as a representative of discharged wastes), together with WHO standards and the average values recorded from surface waters of the Bay of Bengal and the Arabian Sea, are shown in the table below.

Heavy metals in the coastal waters of Tamil Nadu (microgram/litre)

Pollutant	*Point Caiimere*	*Porro Novo*	*Madras*	*River Coounr*	*U'HO Stds*	*Bay of Bengal*	*Arabian Sea*	*Ojjshore waters*	
								Madras	*Tuticorin*
(1)	*(2)*	*(3)*	*(4)*	*(5)*	*(6)*	*(7)*	*(8)*	*(9)*	*(10)*
Cadmium	0.1-0.06	0.2-0.5	14	0.98	2	0.3-2.9	0.2-3.5	0.10-0.8	0.4-2.0
Copper	2-8	0.5-9 9	6-170	4.32	3	1.2-17.5	2.5-22.5	3.00-3.2	4.0-5.0
Lead	I s-2.5	1.5-3.0	7-42	1.38	1	0.5-21.8	4.0-12.5	5.00-6.00	2.0-7.8
Mercury	—	04	I-I.2	0.009	0.01	0.05.0.3	0.03-2.0	0.03-0.06	0.1-0.12
Nickel	0.7-2.0	0 8-2.4	5-17	62	—	0.8-30.3	1.0-16.3	—	—
Zinc	22-40	4.98	15-290	17.6	5	1.9-174	2.9-42.4	—	

Sources : I-Natarajan (1987); 2-Various sources; 3-Daniel (1984);
4 & 5-Somasundaram et al. (1987); 6-8 Qasim & Sengupta (1983);
9, 10-Nanonal Institute of Oceanography, Goa.

The metal concentrations in natural unpolluted seawater, freshwater, Indian rainwater and rainwater in Northern Europe are presented in the table below. The data in this table and in the table at the bottom of the previous page indicate that:

- The coastal waters of Tamil Nadu are polluted with the metals mentioned.
- The concentrations of heavy metals in offshore waters are remarkably high.
- The precipitation in India contains significantly less metals than snow and rain in Northern Europe.

Heavy metals in natural waters (microgram/litre)

Metals	Natural seawater (a)	Fresh water (b)	Raomwater (India) (c)	Rainwater (N. Europe) (d)
Cadmium	0.015-0.118	0.07	NA	NA
Copper	0.892-0.240	1.80	6.R	24
Lead	0.001-0.015	0.20	21.5	25
Mercury	0.01 1-0.033	0.01	NA	0.03
Nickel	0.228-0.693	0.30	01	8
Zinc	0.007-0.640	IO	13.3	70

Source : a,b & d · Bryan (1984); c Fondckar and Topgi (1979)

The heavy metal concentrations (microgram/g dry weight), in coastal sediments in Madras, Parangipettai (Porto Novo) and Kodikkarai (Point Calimere) are shown in the table below. Surprisingly high values were recorded at Kodikkarai and Parangipettai compared to the badly polluted seas near Madras. An explanation for this aberration lies in the high organic content in the sediment samples from Kodikkarai and Parangipettai and the sandy sediment from the Madras samples.

Heavy metals in coastal sediments of Tamil Nadu (microgram/g dry wt.)

Metal	Madras ('82- '83) (a)	Porto Novo ('81-'84) (b)	Point Calimere ('86) (c)
Cadmium	0.3-I .45	10-15.0	E-12.0
Copper	0.16-25.2	29-680	40-80.0
Lead	0.09-80.7	7-12.5	7.8-12.5
Nickel	4.70-13.4	7.5-17.0	10-16.0
Zinc	6.60-50.0	3.5-12.0	432-I 142

Source : a-Daniel (1984); b-various sources; c-Nararajan and Ramesh (1987)

The sediments along the coast and continental shelf north of Madras have a high concentration of organic carbon and trace metals such as iron, copper, manganese, zinc and mercury (Ramasubramaniyan et ***al.,*** 1991; Prabhu et ***al.,*** 1991).

The heavy metal concentration in the body of various biota collected in Madras, Porto Novo and Point Calimere are given in the table below. The essential metals – copper and zinc – showed higher concentrations than such non-essential metals as cadmium, lead, mercury and nickel. The biota analyzed included phytoplankton, zooplankton, molluscs and fish. The Madras biota showed higher values than in the other places due to the high pollutant levels of ambient water.

Heavy metals in marine biota of Tamil Nadu (microgram/g dry wt.)

Metal	Madras (a)	Porto Novo (b)	Point Colimere (c)
Cadmium	2.0-7.5	0.2-0.25	0.02-0.025
Copper	78-530	2-330	0.05-0.15
Lead	0.18-25	0.01-0.03	0.02-0.025
Mercury	0.08-0.9	0.13-0.82	–
Nickel	0.10-22	0.10-0.30	0.01-0.02
Zinc	5-1200	4-1200	1-14

Rajendran et al. (1988) have reported a higher concentration of iron in oyster Crassostrea *madrasensis* (Preston) in the Cuddalore backwaters. Occurrence of trace metals was also noted in the soft tissues of bivalve, gastropods and crustaceans found in the Kalpakkam coastal waters of Tamil Nadu.

According to Daniel (1984), cadmium, lead, copper, nickel and zinc are the main metal pollutants of the Tamil Nadu coast. He has observed that *Halalimus* and *Fredericia* (Oligochaete) tolerate high organic pollution, *Oithona rigidac* and *Centropages orsini* tolerate oil pollution, *Charybdis cruciata* withstand zinc and cadmium, *Sepia aculiate* tolerate copper and *Paphia* spp. tolerate nickel.

Mercury concentrations in water, sediments and biota from the Madras coast have also been investigated. He observes that the concentration in the tissues of marine animals was below the FDA guideline of 1.0 mg/kg (1000 ng/g) wet weight. However, he noted that the mercury level exceeded permissible limits in the gills, muscle and skin of the shark, *Nemipterus javanicus,* and the whole prawn *Penaeus indicus.* Furthermore, he noted that mercury concentrations increased in both water and biological samples along the Madras coast. This is advance warning of increasing mercury pollution.

However, considering the high concentrations of heavy metals in water and sediments, the residues in the biota are surprisingly low.

CHEMICAL INDUSTRIES

Effluents of protein products from a factory in Udagamandalam (Ooty), in western Tamil Nadu, contained high levels of suspended solids and dissolved solids. The dissolved oxygen was very low, as a result of high BOD and COD values. The effluents also contained high amounts of chloride, sulphate, phosphate and toxic levels of nitrates, nitrites and ammonia. Bioassay experiments revealed that the effluents were harmful to the fish in the mountain streams of the area. There was, in fact, a 25-30 per cent reduction of crop seed germination grown on the effluents (Oblisami and Rajannan, 1990).

The effluents from a bleaching company in Mettupalayam, also in western Tamil Nadu, were dull blue in colour and had high amounts of suspended and dissolved solids, with consequent high BOD and COD values. Dissolved oxygen was low and a high concentration of phenols was also reported.

A distillery in Appakudal let out dark brown, alcohol-smelling effluents. The effective concentration of suspended and dissolved solids, as well as BOD and COD, were high. The effluent pH was acidic (5.0), while the DO content was zero. High quantities of chloride (2200 to 7500 mg/l), and ammonia to an extent of 3.3 mg/l, were recorded in the distillery effluents. The effluents also contained organic acids such as propionic acid and buturic acid. Bioassay of fish fingerlings in the distillery effluents revealed that the effluents were highly harmful to the fish (Oblisami and Rajannan, 1990).

The seafood processing plant in Tuticorin discharges water with high concentration of H_2S (>2mg/l), BOD_5 (>30 mg/l), COD (> 100 mg/l) and low pH (6.5). The effluents were mostly untreated or, at best, partially treated.

TANNING INDUSTRY

The leather industry is the fourth largest commercial activity in India. About 80 per cent of the total leather production for export comes from Tamil Nadu, where there are 2200 tanneries, mostly small- and medium-sized and many close to the coast.

Tannery effluents possess a high concentration of dyes and bleach liquors as well as chromium, all of which are very toxic. Tannery wastes also have very high organic contents. The environmental problems connected with tanneries are, in fact, so difficult to handle that there are now practically no such activities in developed countries. As a result, the majority of tanneries are to be found in the poorer countries where environmental laws are lenient or nonexistent.

Oblisami and Rajannan (1990) reported that the effluents from a wattle extracting plant in Mettupalayam were mostly acidic and contained high levels of dissolved solids, sulphate, chloride and tannins (600 to 2000 ppm). The effluents BOD and COD were also high. Irrigation crops with this effluent were found to have adverse effects on seed germination.

Bowonder and Ramana (1986) have recorded groundwater depletion and pollution by small-scale tanneries in the North Arcot District, Tamil Nadu. According to them, the magnitude of the problem worsens due to the interactive effects of population growth, urban development, increased groundwater extraction, depletion of forest cover and the increase in the number of tanneries.

Oceanographic studies of the impact of tannery waste off the Tamil Nadu coast have been carried out by the National Institute of Oceanography, Goa. They showed pollution from tanneries all along the coastal stretch from Madras to Vedaranniyam. The ill-effects of tannery effluents, leading to fish kills in the Palar River, have been mentioned in the press (Narayanamurthy, 1987; *The Hindu,* 1991).

Since the impacts of tannery wastes have increased alarmingly, the Government has requested the Central Leather Research Institute (CLRI), Madras, to find remedies for the crises. The Institute has been carrying out studies on the control of pollution arising from tanning industries and has also been offering industrial consultancy services on pollution control programmes. It has designed, erected, put into operation and maintained a full-scale demonstration effluent treatment plant in Ranipettai since 1977 in a collaborative venture with the industry. Since then, it has designed several effluent treatment systems for various factories in Madras, Ranipettai and Vaniyambadi.

More recently, the CLRI has established a common effluent treatment plant at Vaniyambadi, near Ambur in North Arcot District, for a group of 79 major tanneries. The project is the first of its kind in the state. The plant will collect and treat 2.0 million litres of effluent discharge per day. The cost of the project is estimated at Rs. 2.5 million. The feasibility report furnished by CLRI was approved by the Central Pollution Control Board and Department of Environment, which provided financial assistance to the tune of Rs. 2.5 million. The project was implemented by the Tamil Nadu Leather Development Corporation and the tanning industry (CLRI report).

54.3 Energy production

The per capita consumption of power in Tamil Nadu is estimated to be 280 kwh (1989-90). The State depends primarily on thermal generation (73 per cent) for its energy requirements. The major contribution is from coal-fired and lignite-based thermal stations. Some nuclear power (8 per cent) and hydro-generation (19 per cent), particularly in years of abundant rainfall (Belliappa, 1992), supply the rest of the state's requirement.

The annual coal requirement to meet the present thermal power needs of Tamil Nadu is approximately seven million tonnes. Tamil Nadu is fortunate to have a large lignite reserve, as well as high quality black coal (see table below).

Coal reserves in Tamil Nadu

Name of area	Geological reserve (t)	Minable reserve (t)	Area $(km)^2$
South Arcot (TN)	3300	2100	485
Jayamkondam area in Tiruchi Dr (TN)	1150 appx.	650	120
Bahur area (partly in TN & Pondicherry)	585	Not assessed	52

About eleven million tonnes of lignite is mined a year. The extraction and utilization of lignite for power generation has been entrusted to a public-sector company in Neyveli. Lignite is extracted by open cut mining where the surface over-burden is removed and the lignite is extracted. The Neyveli belt is, therefore, subjected to the environmental consequences of open-cast mining as well as the problems associated with thermal power generation. The peculiar feature of Neyveli, however, is the high water table, which needs constant freshwater pumping to enable extraction of the lignite. Roughly $135 m^3$ of water per minute is required to be pumped out. The constant pumping of such large quantities of water into the surrounding areas exposes them to the risk of water-logging, resulting in soil chemistry changes.

The Jayamkondam area is a virgin site, but it is planned to set up a major power plant here to utilize the lignite available. The problems associated with the mining and utilization in this area are likely to be no different from those faced at Neyveli. The water availability, however, may not be as copious as at Neyveli.

The most important environmental effects caused by electrical power plants are due to thermal and residual chlorine effluents. While fish might survive at a lower temperature, the sharpness of the lethal maximum temperature is such that even the slightest change can cause mortality (Kutty et *al.,* 1986).

Tropical aquatic organisms are more prone to thermal effects because they normally live in a temperature regime which is close to the upper tolerance limit. Temperature may also exert synergistic effects with mechanical stresses as well as chlorine residuals and trace metals present in the effluent waters (Satpathy et *al.,* 1990). Temperature elevation, due to effluent discharges from the power plants in Madras (Kalpakkam and Ennore), has been observed in an area of several square kilometres. The condenser cooling system at Kalpakkam, for instance, uses seawater at the rate of 35 m^3/s, which is then discharged at high temperatures. The rise at the outfall, as compared to the intake, is found to range between 8 and 10°C. Ecological changes included a marginal decrease in dissolved oxygen, pH, and primary productivity (Durairaj, 1990). The movement of the thermal plume on the coast has not, led to fish kills, but significant changes in sedentary fauna and flora have been recorded in the condenser outfall area (Suresh et *al.,* 1990). The influence of thermal effluents on the phytoplankton ecology of the mangrove estuaries of Tuticorin on the Tamil Nadu coast was studied by Santhanam (1990). He has attributed the cause for poor species' diversity to the impact of direct mixing of thermal effluents. Another study recorded a 60 per cent zooplankton mortality due to entrainment.

On the sandy shores, where the impact of the thermal plume is observed, *Emerita asiatica* seemed to be the first order impact organisms. There was also a marked reduction of biota upto a few kilometres on the adjacent shores. When the ambient temperature ranged between 37.0 and 37.6°C, almost all the macro-epifauna and epi-flora perished, except for Periwinkles and Cthamalid Barnacles.

Chlorine is applied to the seawater at the rate of 25 kg per hour at the cooling water intake about 400 metres from the shore. (This is being practised at Kalpakkam Nuclear Power Plant, about 60 km south of Madras.) Chlorine is used to kill the growth of marine organisms, which build up on the walls of the power plant cooling systems. The excess chlorine has caused physical damage to the cells of the phytoplankton, leading to a reduction in photosynthetic efficiency as well as a decrease in primary organic productivity (Ahamed ef *al.,* 1990). In addition to these ill-effects, chlorine added to the seawater also transforms its chemistry, forming a complicated Trihalomethane (THM) compound that is potentially a carcinogenic agent. Excess chlorine with ammonia derivatives form compounds such as chloramines and bromamines, which are more persistent than free halogen and hence, potentially more toxic. Some of them are biomagnified and concentrations should, therefore, be checked in commercially important fish and crustaceans.

The increase in usage of nuclear energy for the production of power has increased the amount of radioactive wastes (Rangarajan et *al.,* 1991). The Madras Atomic Power Station (MAPS) is a clear example of this (see table below and on facing page, top).

Radioactivity of Tritium in MAPS effluents (T Bq)

1985		1986		1987		1988	
L.d.*	A d **	L.d.	A.d.	L.d	A.d.	L.d.	A.d.
0.015	18	0.27	41	0.057	54	0.089	373

Source : Rangarajan et al., 1991

* Liquid discharge ** Atmospheric discharge

During the power plant operations, tritium is routinely released into the environment from the reactors, through atmospheric and liquid discharge routes. On release into the environment, tritium (t ½ = 12.3 years), being an isotope of hydrogen, assimilates readily with the water component of the atmospheric, aquatic and biological systems. Although tritium occurs in nature – formed by the action of cosmic rays on the earth's atmosphere – nuclear installations are, by far, the greatest source of tritium in the environment. The nuclear industry insists that such releases pose no risk to the public, but there is mounting evidence linking tritium emissions with birth defects and cancers (Gardner, 1990).

Yearwise increase in generation of radioactive wastes

Year	*Atmospheric discharge (A.d) (T Bq)*	*Liquid discharge (L. d) (T Bq)*
1989	1147 6	922
1990	829.5	141.1

Though scientific reports (Rangarajan et *al.,* 1991) reveal that tritium levels in the waters of habitats adjacent to MAPS are low (3 1 - 240 Bq/l), the media has been regularly highlighting the hazardous effects of these plants to the public. If the proposal to establish a nuclear power plant at Kudangulam, near Tirunelveli, materializes, the threat due to radioactive pollution could be even more severe,

54.4 Oil pollution

Activities responsible for oil pollution of the marine environment in Tamil Nadu include oil exploration, oil refining, oil transport, oil spills and leakages from ships and fishing trawlers as well as from petrochemical industries. The places where such activities take place and their magnitude are presented in the table alongside.

Activities related to marine oil pollution in Tamil Nadu

Activity	Area	*Other details*
Oil exploration (Drilling wastes. production wastes and sanitary wastes)	Kareri Delta, Palk Bay	Offshore and nearshore
Oil production (same as above plus free emulsion tank bottom sludge etc.)	Koilkalappat Narimanam Bhuvanagiri	25,000 t 30.000 bbl/d*
Oil transport (ship wastes, tank washings, spills etc.)	Madras and Tuticorin	3 x 10^6 t/y
Oil refining [oil from leaks, spills, effluents tanks draw off etc.)	Madras	5 x Id t/y
Petrochemicals productton (by-products productron and industrial wastes).	Madras Gulf of Mannar	75,000-100,000t/y

' billion barrels per day

The southern Bay of Bengal, the Gulf of Mannar region, forms a part of one of the two major tanker routes (Qasim and Sengupta, 1983). The range of concentration dissolved petroleum hydrocarbons in the Bay of Bengal and the Arabian Sea are 0 to 28.2 and 0 to 42.8 microgram/kg, the average being 4.6 and 15.8 microgram/kg respectively. The particulate petroleum residues range from 0 to 69.8 mg/m^2 in the Bay of Bengal and from 0.3 to 112.2 mg/m^2 in the Arabian Sea (UNEP, 1985).

The dissolved PHC in the Pichavaram mangrove waters (Parangipettai) ranged from 5 to 15 microgram/litre and in Kodikkarai (Point Calimere) from 8 to 20 microgram/litre (Natarajan and Ramesh, 1987). In the Madras area, values ranging from 4 microgram/litre to as high as 108 microgram/litre in water and from 1.5 to 3.5 microgram/g dry weight of sediments were reported. The values recorded along the Tamil Nadu coast are slightly less than those recorded in other parts of the world. Thus, at present levels, they do not pose any threat to marine life. Intensification of oil exploration during the next five years in the Godavari basin and the Palk Straits area should, however, cause concern. Continuous monitoring of both areas, to establish a scientific database and to assess the environmental impact and degradation is essential.

54.5 Agriculture

Tamil Nadu has a total cropping area of 7.1 million ha, of which about 2.65 million ha are irrigated. The most commonly used pesticides are HCH, malathion, parathion, monocrotophos and sevin (cabaryl). About 8,000 t of solid and 500,000 litres of liquid pesticides are used in agriculture. (Agro Stat., Dept. of Agriculture, Govt. of Tamil Nadu). In addition, DDT is still used in significant amounts for sanitation purposes.

Pesticides recorded in Tamil Nadu coastal waters include DDT, lindane (r-HCH), endosulfan and heptachlor. The concentration of these pesticides in the coastal waters and sediments from Madras and Parangipettai are presented in the table alongside.

Pesticides in coastal waters (microgram/litre) and sediments (microgram/g dry weight) of Tamil Nadu

Pesticides	*WATER*		*SEDIMENTS*	
	Madras (a)	*Parangipettai (b)*	*Madras (a)*	*Parangipettai (b)*
DDT	9 224	5.2	0.04 3.05	10 44
Lindane	6 761	0.9	003 10'1	I 96
Endosulfan	2 578	0.1	0.00: 519.2	I 33
Heptachlor	6 690	–	0.001 18 37	–

Sources a – Daniel (1984) b - - Rajendran (1984)

The Madras waters had higher values than the Parangipettai waters. But higher values have been recorded in Parangipettai sediments, than in Madras. The bioaccumulation of these pesticides in marine organisms is expected to be considerable.

Analysis of pesticide residues in marine fish revealed that the highest concentrations were found in Black Pomfret followed by tuna, vala and mackerel. However, their concentration was well below the level stated by FDA to be a potential hazard to human health. Yet, pesticide residue in fish should be viewed seriously, as ongoing bioaccumulation can lead to future health hazards for consumers.

Studies carried out by Ramesh et *al.* (1990), on the persistent organochlorine residues in green mussels ***(Perna viridis)*** from the coastal waters of South India, revealed that the concentrations of HCH and DDT ranged from 3 to 33 ng/g on wet weight basis. On the other hand, PCB levels were apparently lower, varying from 1 .0 to 7.1 ng/g wet weight. The residue pattern of organochlorine in mussels is, in the main similar to those in Indian human samples.

The coastal marine pollution of HCH in India ranks with the worst contaminated areas in the world. Ramesh et ***al.*** (1991) have studied the distribution and behaviour of persistent organochlorine insecticides (HCH and DDT), in paddy soil and in the sediments of the Vellar watershed and the Pichavaram mangroves near Parangipettai in Tamil Nadu. Their study indicated that the relative flux of residues in the aquatic environment in tropical watersheds is smaller than the amount volatilised in the atmosphere. The sandbar built between the Vellar and Kollidam (Coleroon) estuaries seems to act as effective traps for heavy metals and pesticides, preventing their entry into the coastal waters (Rajendran,l984).

The pesticide concentrations recorded in different marine biota are presented in the table alongside.

Pesticides in marine biota of Tamil Nadu (microgram/kg)

Organism	*Total DDT*	*Lindane*	*Endosulfan*
Plankton	8.11	1.72	0.20
Crassostrea madrasenis	3.37	0.96	0.39
Meretrix meretri	2.87	0.90	0.37
Katalysia opimo	*3.06*	0.78	0.40
Mugil cephalus	3.65	1.02	0.37
Therapon jarbusa	3.73	1.12	0.45
Mystus gulio	3.43	0.73	0.36
Siganus java	2.68	1.30	0.48

Source : Rajendran (1984)

Among the pesticides, lindane levels are high in water, endosulfan in sediments and DDT in biota. Among the biota, the highest concen-(rations were recorded in plankton. Special studies of biomagnification of pesticides in tropical habitats are needed.

Pesticides and heavy metals show high concentrations during the monsoon season in surface waters, indicating increased inputs from river run-offs and increased land drainage. The sediments show high concentrations during post-monsoon and summer months, through the settling of particulate matter by precipitation and flocculation. During summer, the petroleum hydrocarbons record maximum values due to the absence of freshwater flow and the stagnant conditions. The minimum values occur during the monsoon months, when dilution, because of flooding, takes place.

Bad land management in agriculture and forestry has led to an excessive loss of fertile soils. The increased transports of sediments have also caused damage to fisheries. Siltation prevents the natural exchange of water between estuaries and the sea, thereby affecting the salinity levels. This, in turn, affects marine fish and shrimp reproduction negatively.

55. *REFERENCES*

AHAMED, M.S., SURESH, K., DURAIRAJ, G. and NAIR, K.V.K. 1990. Observations on the cooling water chlorination and productivity of entrained phytoplankton at Kalpakkam, east coast of India. *IN: BARC* Proc. Bombay. pp 241 243.

BOWONDER, B. and RAMANA, K.V. *1986. Environmental degradation and economic development.* A case study of a marginally productive area. Department of Environment, New Delhi. pp. l-36.

BELLIAPPA, P.M. 1992. Coal and the clean environment with special reference to the State of Tamil Nadu, India. Proc. *Intl. conf. on environmentally sound coal technologies: Policy issues and tech. options.* Madras, India. Jan. 15-18.1992 PP.9.

BRYAN, G.W. 1984. Pollution due to heavy metals and their compounds. IN: *Marine Ecology,* Ed. 0. Kinne. John Wiley & Sons, New York, Vol. V. part 3. 1289-1432.

CHANDRAMOHAN, D. 1971. lndole acetic acid synthesis in the sea. Proc. *Ind. Acad. Sci. (Plant Sri.)* 73:105-109.

DANIEL, A. 1984. The effect of pollution on some organisms in the zooplankton, benthos and nekton, contributing to the food chain in the marine environment. *Completedprojects under environmental research programme: Objectives and salient findings.* ENVIS. Govt of India. Project 36/ERC. pp.58-59.

DURAIRAJ, G. 1990. Thermal ecology in the vicinity of a power plant cooling water outfall in coastal waters. *IN: BARC. Proc.* Bombay. pp. 272 - 279.

FONDEKAR, S.P. and TOPGI, R.S. 1979. Trace analysis of pollutants in rain water at Goa. *Mahasagar.* (Bull. Natl. lnst Oceanog.), 12:49-5 1.

GARDNER, M. 1990. Results of a case-control study of leukemia and lymphoma among young people near Sellafield nuclear plant in West Cumbria. *British Med. J. 300.* pp.423-429.

KASIM, M.H., BALASUBRAMANIAN, T.S., RAJA PACKIYAM, S. and RANGASAMY, V.S. 1991. Fish mortality due to pollution by industrial effluents in inshore waters of Kayalpatnam. Mar. *Fish. Inf. Ser.* No 113, July-Sept. 1991. pp 26-28.

KRISHNAMURTHY. V. 1986. 'Seaweed cultivation — A Review'. IN: Ed. V. Krishnamurthy. *Mar. Biol. and Mariculture.* Mem. Salem Inst. Exp. Biol. No 2:112-125.

________________ . 1991. Seaweed Resources, IN: Ed. R. Natarajan *et al. Coastal Zone Management in Tomil Nadu. India.* pp.215-221.

KUTTY,M.N., KASIM, H.M., SANTHANAM, R. and SUKUMARAN, N. 1986. Thermal pollution of coastal waters and its effect on fish survival. *IN: Proc. Symp. Coastal Aquaculture, 4:1367-1376.*

LAKSHMANAPERUMALSAMY, P. and PURUSHOTHAMAN, A. 1982. Heterotrophic bacteria associated with seaweed. *Proc. Ind. Acad. Sci. (Plant Sci.)* 91:487-493.

LAKSHMANAPERUMALSAMY, P., CHANDRAMOHAN, D. and NATARAJAN, R. 1984. Fin rot and other diseases in marine fishes. *Proc. hd. Acad Sci.* (Animal Sci), 93:107-l 14.

NARAYANAMURTHY. 1987. Murder by poisoning: Death of the Palar. *IN: Thefightfor survival- People's action for environment.* Ed. Agarwal et al., Centre of Sc. & Envt. Pub. pp. 89-101.

NATARAJAN, R. and RAMESH, *S.* 1987. *Assessment of water quality along Tamil Nadu coast.* Final Report. Central Board for Prevention and Control of Water Pollution, New Delhi, Sponsored research project. (Mimeograph).

______________________ 1987. Ecology of the human pathogen E. *Co/i* in Porto Novo coastal environs. Contribution IO Murine Sciences, Dr. S.Z. Quasim's sixtieth birthday felicitation volume. pp.67-84.

NAGARAJAN, R. *1990. Factors influencing Wader (Ciconiformes and Charadriiformes) populations in the wetlands of Pichovarum. Tomil Nadu, S. India.* M.Phil thesis, Bharathidasan Univ., Thiruchirappalli, 62p.

NAYAR, K.N. 1987. Technology of *oyster* farming. *Bull. Cent. Mar. Fish. Res. Inst. 38:59-62.*

NAYAR, K.N.. MAHADEVAN, S., RAO, K.S., SIVALINGAM, D. and RAMADHASS, K. 1988. Exploitation of molluscan shell deposits in Vaigai estuary at Athankarai. Bull. Cent. Mar. *Fish. Res. Inst., 42:35-39.*

OBLISAMI, G. and RAJANNAN, G. 1990. Impact of industrial pollution on the microbiology of Bhavani river and environs. *IN: Environmental Research* Executive Summaries of Completed Projects, Vol. 1. Ministry of Environment & Forests, Government of India. pp 112-l 13.

PRABHU, S.K., SUBRAMANIAN, B. and MAHADEVAN, A. 1991. Occurrence and distribution of heterotrophic bacteria off Madras coast, Bay of Bengal. *Ind. J. of Mar. Sci.* Vol. 20., June 1991, pp. 130-133.

PILLAI, C.S.G. 1971. Distribution of corals on a reef at Mandapam (Palk Bay), S.India. *Mur. Biol. Assn. India I 1(1&2):* 62-72.

__________ 1973. Coral resources of India with special reference to Palk Bay of Gulf of Mannar. *Proc. Symp. Living Rex* of *Ind.* (CMFRI. 700-705.

QASIM, S.Z. and SENGUPTA, R. 1983. Marine pollution studies in India. IN: *Water Pollution and Management Review.* ED. C.K. Varshney. South Asian Publishers Pvt. Ltd., New Delhi 139-159.

RAJENDRAN, N. 1984. *Organochlorine pesticide residues in Vellar estuary.* Ph.D. thesis. Annamalai Univ., Tamil Nadu. unpublished, 317 p.

RAJENDRAN, N., TAGORE. J. and KASINATHAN, R. 1988. Heavy metal concentrations in Oyster, *Crassostrea madrasensis* (Preston), of Cuddalore backwaters, southeast coast of India. *Ind. J. Mar Sci.* Vol 17. June IYR8. pp. 174-175.

RAJENDRAN, N., MAHALINGAM, R. and GOPINATH, K. 1987. Ecological conservation of seagrass beds in the Gulf of Mannar, India. *Envt. Conservation* pp. 265-268.

RAMACHANDRAN, S. 1990. Marine Pollution in Tamil Nadu — A status report. *Proc. Intl. Symp. Mar. Pollution,* 1990 pp. 143-160.

RAMAMURTHY.T., RAMESH, S. and NATARAJAN, R. 1985. Incidence of three new *Salmonella* serotypes — *S. irumu, S. panama* and *S. lexington* from the southeast coast of India (Porto Novo) *Ind. J. Med. Res. 81:558-560.*

RAMASUBRAMANIYAN, R., VALSARAJ, C.P. and RAO, V.N.R. 1991. Sewage pollution in the coastal waters of Madras, east coast of Ind. *Ind. J. Mar. Sci.* Vol 20, Dec 1991. pp.259-262.

RANGARAJAN, PARAMESWARAN, VS., AMALRAJ, R.V., KRISHNA, L.V.. SUNDARAJAN, A.R., NAIR. K.V.K. and IYENGAR, M.A.R. 1991. Impact of a coastal nuclear power plant: The Kalpakkam experience. IN: Ed. R Natarajan *et al., Coastal Zone Management in Tarnil Nadu.* 1991. pp 294-302.

RAMESH, A., TANABE, S., SUBRAMANIAN, A.N., MOHAN, D., VENUGOPALAN, V.K. and TATSUKAWA. R. 1990. Persistent organochlorine residues in Green Mussels from coastal waters of South India. *Mar. Poll. Bull.* Vol 21, No 12., pp.587-590.

RAMESH, A., TANABE, S., MURASE, S., SUBRAMANIYAN, A.N. and TATSUKAWA, R. 1991. Distribution and behaviour of persistent organochlorine insecticides in paddy soils and sediments in the tropical environment: A case study in South India. *Environmental Pollution. 74:* pp. 293-307.

RAVICHANDRAN, S. 1987. Water quality studies in Buckingham Canal (Madras, India) — A discriminant analysis. *Hydrobiologia 154,* 121-126.

SALM, R.V. *1975. Sri Lanka, Southeast and Western India, Pakistan. Promotion of the establishment of marine parks and reserves in the northern Indian Ocean including the Red Sea and Persian* Gulf. IUCN Publ. New series. pp. 124-128.

SANTHANAM, R. *1990. Influence of thermal effluents on the phytoplankton ecology of mangrove estuaries of Tuticorin. southeast coast of India.* IN: Intl. Symp. on the ecology of mangroves and related ecosystems. Sept. 1990. Mombasa, Kenya. Sessions: Pollution of coastal systems.

SATPATHY, K.K., VENUGOPALAN, V.P., NAIR, K.V.K. and MATHUR, P.K. 1990. Environmental and operational problems and their assessment at power plant sites: The Kalpakkam experience. *Proc. of a Natl. Symp. on Envt: Scientific approach to Environmental issues.* BARC, Bombay, Feb 3-5, 1992. pp. 8-10.

SIVAKUMAR, V., THANGARAJ, G.S., CHANDRAN, R., LAKSHMANAPERUMALSAMY, P. and RAMAMURTHY, K. 1986. Studies on faecal coliform in an estuarine environment of Porto *Novo. Proc. Symp. Coastal Aqua., 1986.* 4:1330-1338.

SKILLMAN, R.A. 1982. *Tuna fisheries statistics for the Indian Ocean and Indo-Pacific.* Tuna Dev. & Manag. Prog., Colombo. Sri Lanka. I.P.T.P/82/WP/1.

SURESH, K.. SHAFIQ AHAMED. M. and DURAIRAJ, G. 1990. The impact of heated effluents from a power plant on the macrofauna and meiofauna of a sandy shore. IN *BARC Proc.* Bombay pp.21-24.

SOMASUNDARAM. M.V., RAVICHANDRAN, G. and RAMASAMY, A. 1987. Pollution in Coovum estuary and adjoining wells. *IN: Proc.Natl. Sent. on Estuarine Management,* Govt. of Kerala, Trivandrum. (In press).

THE HINDU. Survey of the Environment. 1991. I. Tamil Nadu-Facing threat on several fronts. 2. Pondicherry · In the effluent territory. Reports by N. Kalyanasundaram and S. Natarajan. p.72.

THORHAUG. A. 1983. Healing Carribean Coastlines. *Siren* 22.21-26. (Original not referred)

THOMAS, P.A. and GEORGE, R.M. 1987. Gorgonid resources of India. *Mar. Fish Info. Serv.* T & E Ser. 74: 1-3.

UNEP. 1985. IUCN/UNEP:Management and conservation of renewable marine resources in the South Asian Seas region. *UNEP Regional Seas Reports and Studies* No 62. UNEP, 1985.

VENKATARAMANUJAM, R., SANTHANAM, R. and SUKUMARAN, N. 1981. Coral resources of Tuticorin (South India). *Proc. 4th Intl. Symp. Coral Reefs,* Manila, I :259-262.

WAFAR, M.V.M. 1986. Corals and coral reefs of India. *Proc. Ind. Acad.* Sri., (Anim/plant): Suppl. 19-43.

WELLS, S.M. *1988. Coral reefs of the world. India.* IUCN 79-94.

APPENDIX XXVII

Institutions engaged in environmental research, monitoring and enforcement

GOVERNMENT ORGANIZATIONS

Tamil Nndu State Pollution Control Board (TNPCB)

This is the main governmental institution responsible for environmental planning, management and monitoring of the water, soil and air media.

All industries in the state function with permission from the Board, and their effluents and waste disposals are periodically monitored by it. Furthermore, the establishment of a new industry needs prior permission, which is granted only when the proposed industry instals treatment plants. The Board has been empowered to take action on suspected ill-effects due to factory effluents. The main objective of the TNPCB is pollution control.

Department of Environment (DOE)

The Department of Environment, Forests and Wildlife, New Delhi, is the second biggest governmental organization engaged in environmental research in Tamil Nadu. The DOE also sponsors scientific projects in different universities, research institutions and post-graduate colleges.

Council for Scientific and Industrial Research: (CSIR)

This quasigovernmental organization is involved in environmental research. The Council has regional laboratories in different states and carries out research in environmental and multidisciplinary scientific fields. The CSIR also conducts competitive exams nationwide for postgraduate students and funds scientific projects.

Indian Council of Agricultural Research (ICAR) **and Indian Council of Medical Research** (ICMR)

ICAR and ICMR are quasigovernment research bodies involved in research activities of a multidisciplinary nature. Higher studies and research pertaining to fisheries are usually sponsored by ICAR.

OTHER SCIENTIFIC ORGANIZATIONS

There are several other departments attached to Central Government Ministries, such as the Department of Science and Technology (DST), Dept. of Atomic Energy (DAE), Dept. of Biotechnology (DBT), Dept. of Ocean Development (DOD), Defence Research Agency and others which are actively involved in sponsoring and co-ordinating environmental work in Tamil Nadu.

Research organizations, such as the Forest Research Institute, Wildlife Institute of India, Indian Institute of Technology, and the Fisheries Research Institutes (Central and State), also participate in environmental research studies. The Central Marine Fisheries Research Institute (CMFRI), Central Institute of Brackishwater Aquaculture (CIBA), Central Inland Capture Fisheries Research Institute (CICFRI) concentrate on environmental studies in addition to aquaculture practices. The Zoological Survey of India (ZSI) has a separate block on marine biology; it is also involved in environment monitoring and management studies.

The National Environment Engineering Research Institute (NEERI) and Central Electrochemical Research Institute (CECRI) are also Central Government affiliated bodies effectively involved in environmental research activities. A research wing of the Department of Ocean Development, in collaboration with CECRI, has recently initiated efforts to collect ocean data in Madras at the CSIR complex. The Central Leather Research lnstiture (CLRI) in Madras extends consultancy services in environmental monitoring in addition to its involvement in scientific activities to bring down pollution in ianneries, the major industry of Tamil Nadu. The Central Rice Research Institute, in Thanjavur District, and the Indira Gandhi Centre for Atomic Research (IGCAR), in Kalpakkam, are also Research institutions where environment-oriented research work is going on.

The National Institute of Oceanography in Goa (NIO) is engaged in oceanographic and environmental studies along the Tamil Nadu coast.

UNIVERSITIES

Almost all the universities in Tamil Nadu offer courses and conduct research work in the field of environment. Most of the postgraduate institutions and autonomous colleges that have partial affiliation with the University Grants Commission (UGC) are also involved in environment activities. The Anna University, Madras, has a separate department, 'Centre for Environment Studies', where an M.Tech course on pollution studies is offered. The Water Resources Department of the same university has a 'Ocean Data Centre' which was recently started in collaboration with the NIO, Goa. The Remote Sensing Centre of the same university carries out studies on coastal mapping in Tamil Nadu. The Centre for Advanced Study in Marine Biology, Annamalai University, in Parangipettai, a major centre for higher learning on marine studies. In addition, the 'School of Ecology' at the Central Pondicherry University offers courses in ecological studies.

NONGOVERNMENTAL ORGANIZATIONS

The Madras Science Foundation, the SPIC Science Foundation, the C.P. Ramaswami Iyer Research Foundation and a few other private institutions are nongovernmental bodies where environmental research and awarenesss campaign programmes are routinely carried out in Tamil Nadu and Pondicherry.

APPENDIX XXVIII

Legislation against threats to the marine environment

FISHERIES

The Indian Fisheries Act was passed in 1897. The Indian Fisheries Tamil Nadu Amendment Act, passed in 1927. was again amended in 1980. The objectives of these legislations are :

- To prohibit the use of dynamite and poison in all waters within its jurisdiction.
- The prohibition or regulation of the use of fixed engines for the capture of fish, and the construction of weirs.
- The prohibition or regulation of the use of nets with a mesh below a minimum size.
- The prohibition or regulation of the capture or sale of all or any kind of fish during any closed season.
- The total closure of any water for a period not exceeding two years.
- To provide suitable penalties for breach of the law and of the rules they cover.
- Vesting the Government with the exclusive privilege over chanks and chank fisheries.

In 1981, the Maritime Zones of India (Regulation of Fishing by Foreign Vessels) Act was passed.

TANKER SAFETY

The regulation of tanker traffic in coastal waters is as complex as any coastal water use management issue and, perhaps, typifies, better than most issues, the potential disparity between a relatively narrow-focus central regulatory programme and a state's effort at comprehensive coastal water planning as part of its coastal zone management programme.

ENVIRONMENTAL PROTECTION

It is important to note at the outset that environmental legislation in India carries constitutional authority too. The directive principles of state policy requires that the state should protect and improve the environment. A corresponding duty has been imposed on every citizen. The law made for the protection of the environment also enjoys immunity from judicial scrutiny. The Constitution prescribes division of legislative powers between the Union Parliament and the State Legislatures.

TAMIL NADU (POLLUTION CONTROL) ACTS

The Tamil Nadu Pollution Control Board enforces the following regulatory enactments on environment and pollution control:

i) Water (Prevention and Control of Pollution) Act, 1974, amended in 1988.

ii) Air (Prevention and Control of Pollution) Cess Act, 1981, as amended in 1987.

iii) Water (Prevention and Control of Pollution) Act, 1977,

iv) Environment (Protection) Act, 1986.

SITING NEW INDUSTRIES

Guidelines have been evolved for siting new industries, prescribing the distance from sensitive areas and restricting certain industries within one kilometre from specified water sources.

Areas to be avoided in siting industries are:

- Ecologically and/or otherwise sensitive areas: at least 25 km, depending on the geoclimatic conditions.
- Coastal areas at least 500 m from high tide limit.
- Floodplain of the river-line system; at least 500 m from floodplain or modified floodplain effected by dam in the substream or by flood control system.
- Transport/communication system at least 500 m from highway and railway.

Note : Ecological and/or otherwise sensitive areas include religious and historic places, archaeological monuments, scenic areas, hill resorts, beach resorts, health resorts, coastal species, estuaries rich in mangroves, breeding grounds of specific species, gulf areas, biosphere reserves, national parks and sanctuaries, natural lakes, swamps, seismic zones, tribal settlements, areas of scientific and geological interest, defence installations, border areas (international) and airports.

APPENDIX XXIX

Other publications on the marine environment

AMANULLAH. 1992. Epizootic Ulcerative Syndrome in fish of Cauvery river at Trichy. (Persona1 communication).

AYYAKANNU, K. 1990. The Coleroon estuary and adjoining seaboard (South India). A holistic study of benthic ecology *Environmental Research.* Executive summaries of completed projects. Vol. I Ministry of Envt. and Forests, New Delhi. 35p.

BARBIER, M.D., JOLY, A.S. and TOURRES, D. 1973. Hydrocarbons from sea water. *Deep sea research 20:305-314.*

BAY OF BENGAL PROGRAMME. *Penculture of shrimp in the backwaters of Killai,* T.N. BOBP/WP/35.

CHACKO. P.I., ABRAHAM, J.G. and ANDAL, R. 1953. *Report on the survey of flora, fauna and fisheries of Pulicat Lake, Madras State, India.* (1951-52). Contribution from the Freshwater Fisheries Biological Station, Madras No. 8. 20p.

EDWARD, P.J.K. and AYYAKANNU, K. 1991. Temporal variation in annual production of *Tellina nobilis* and *Tellina cuspis* in a tropical estuarine environment. *Mahasagar.* Vol 24. No 1 (June) 1991. pp. 22-29.

EVANGELINE, T. 1975. Hydrobiology of the estuaries and backwaters of Ramanathapuram District, T.N. IN: R. Natarajan (Ed), *Proc. Symp. Estuarine. Biol.,* Annamalai Univ. pp. 193-21 1, Hindustan Pub. Corpn. (India), Delhi 110007.

FRANKLIN, GURUSWAMY, T.V. and NATARAJAN, T. 1991. Coastal survey by remote sensing. *Coastal Zone Management in Tamil Nadu, India.* Ed. R. Natarajan *et al.* pp 62-65.

GANAPATHY, R. and SAKTHIVEL, M. 1991. Prawn farming. *Coastal Zone Management of Tamil Nadu. India.* Ed. R. Nata:ajan *et al.* pp 186-191.

JAMES, P.S.B.R. and NAJMUDDIN, M. 1986. Recent observations on physio-chemical characteristics of the lagoon along the Palk Bay at Mandapam with a note on the possibility of its utilization for large scale fish culture. IN: *Proc. Symp. Coast. Aqua.,* 1986.4 : 1039-1046.

JAYABALAN, *N. 1980. Studies on Silver Bellies (Pisces: Leiognatidae) and their associated bioluminescent bacteria in Porto Novo waters.* Ph.D. thesis, Annamalai Univ., Annamalainagar.

JEBANESAN. A. *1989. Hydrobiological study of the river Cooum in Madras, South India, with special reference to aquatic Hemipterans.* Ph.D. thesis, Loyola College, Madras.

JEGADEESAN, P. *1986. Studies on environmental inventory of the marine zone of Coleroon estuary and inshore waters of Pazhayaru, southeast coast of India.* Ph.D. thesis. CAS in Marine Biol., Annamalai Univ., Annamalainagar. 277p.

JERALD, J. A. 1992. *Integrated environmental research programme on River Cauvery.* Final report to the Ministry of Environment & Forests. New Delhi Univ. VI.B. 23 p.

JHINGRAN, V.G. 1985. Cauvery and other estuaries on the east coast. Estuarine fisheries. *IN: Fish and fisheries of India.* Ed. V.G. Jhingran. Revised & Enlarged 2nd Ed. p. 222.

____________ 1985. Pulicat lake. Estuarine fisheries. *IN: Fish and fisheries of India.* Revised & enlarged 2nd edn. Ed. V.G. Jhingran. pp. 236-241.

____________ 1985. The Vellar estuary and Killai backwaters. Estuarine Fisheries. IN: *Fish and Fisheries of India.* Ed. V.G. Jhingran. Revised & Enlarged 2nd edn. pp. 224-225.

____________ 1985. The Adyar estuary fisheries. *IN: Fish and Fisheries in India.* Ed. V.G. Jhingran. Revised & enlarged 2nd edn. pp 222-224.

JOHNSTON, R. 1984. Oil pollution and its management. IN. Ed. 0. Kinne *Marine Ecology,* Vol.V. Part 3. John Wiley & Sons. New York. pp. 1433-1582.

KALAYANASUNDARAM, N. 1991. Tamil Nadu facing threat on several fronts. Environmental Hotspots. *The Hindu, Survey of the Environment 1991.* pp. 72.

KANNAN, K. S., TANABEE, RAMESH, A., SUBRAMANYAM, A.N., and TATSUKAWA, R. 1992. Persistent organochlorine residues in foodstuffs from India and their implications on human dietary exposure, J. Agric. ***Food* Chem.** 40:518-524.

KRISHNAMURTHY, K. and JAYASEELAN, M.J.P. 1986. Prospects of aquaculture in a mangrove ecosystem. Proc,. ***Symp. Coast. Aqua. 4:1059-1067.***

KRISHNAMURTHY, K. and SUNDARARAJ, V. 1974. Studies on phytoplankton pigments in Porto Novo waters (India). II. Backwaters. J. ***Exp. Mar Biol. Ecol.,*** Vol. 14.. pp. 285-294.

KRISHNAN, P. and SAMPATH, Y. 1976. A survey of Pulicat lake and its fisheries. ***Madras*** J. ***of Fish.*** Pub. of Director of Fisheries, Tamil Nadu Vol. VII. pp. 89-91.

LAKSHMI, K.K. 1990. Seagrass ecosystem of Coromandel Coast. Envt. ***Res.,*** Govt. of India. 1990. p 83

LAW, R.J. 1981. Hydrocarbon concentration in water and sediments from U.K. marine water. Determination by fluorescence spectrophotometry. ***Mar Poll. Bull 12(5), 153-157.***

MANISERI, M.K. 1982. On the fishery of juveniles of ***Penaeus semisulcatus*** along the Tirunelveli coast, Tamil Nadu. ***Ind. J. Fish. 29:20-28.***

MARTIN, A. 198 ***I. Studies on vibrio parahaemolyticus and allied vibrios from the Pitchavaram mangrove-Killai backwater complex interconnecting the Vettar and*** Coleroon ***estuarine system.*** Ph.D thesis, Annamalai Univ., Annamalainagar.

MURUGAN. A. and AYYAKANNU, K. (1991). Ecology of Uppanar backwater, Cuddalore: I. Physico-chemical parameters. ***Mahasagar.*** Vol 24. No 1 June 1991. pp. 31-38.

MURUGAN, A. 1991. Ecology of benthic macrofauna in Cuddalore- Uppanar backwater. Southeast coast of India. ***Ind. J. Mar. Scs.*** Vol 20. Sept 1991 pp. 200-203.

NARASIMHAN, K.A. 1988. Recent advances in the hatchery production of seed of some commercial bivalves in India. ***Ind. Fish. Assn., 18:21-25.***

PERUMAL, P. 1991. Humic acids, photosysthetic pigments and physiochemical features of Vellar Estuary. ***J. Ecotoxicol. Environ. Monit.*** 1 (3) 192-197 pp.

PRABHU, S.K., SUBRAMANIAN, B. and MAHADEVAN, A. 1991. Mycoflora of sediment and waters of the Madras coast, Bay of Bengal. ***Ind. J. of Marine Sci.*** Vol 20., Sept. 1991, pp 226-228.

PRASADAM, R.D. and KADIR, P.M.A. 1988. Experimental pen and cage culture of grey mullets in the Pulicat lake. IN: M. Ed. Mohan Joseph. ***The first Indian Fisheries Forum.*** Proc. Asian Fish. Soc. Indian Branch, Mangalore. pp. 143-145.

QUART, A. 1992. Life and death in the Mangroves. 'Outlook', ***Bangkok*** Post, section three Vol XLVII No 238. Aug. 1992.

RAJAMANI ***et al.*** CLRI activities in environmental pollution control (tannery waste treatment, disposal and utilization) ***CLRI Report: Environmental Technology Area.*** CLRI, Adyar, Madras. pp. I-IO.

RAO, K.S., SIVALINGAM, D., NAIR, P.N.R. and UNNITHAN, K.A. 1987. Oyster resources of Athankarai estuary, southeast coast of India. ***Bull. Cent. Mar. Res. Inst.*** 38:17-29.

RAO, P.S. 1991. Quaternary Geology. IN: Ed. R. Natarajan ***et al. Coastal Zone Management in Tamil Nadu. India. 1991*** p 31.

RAMESH, A. ***1986. Ecophysiologicalstudies of luminous bacteria of vellar estuary.*** Ph.D. thesis, Annamalai University, Annamalainagar.

RAY, ***1991. A Mangrove ecosystem in India.*** A keynote address in Nat. Sem. on Consv. and management of mangrove ecosystem, organised by Bidham Chandra Krishi Visva Vidhyalaya, Kalyani. Dec. 1991 pp. I-9.

RAY, P.K., PRASAD, A.K. and NANDAN, R. 1985. Pesticides — Major Environmental Problem. ***Sci. and Culture*** 5 1:363-37 1.

SANTHANAM, R., KRISHNAMURTHY, K. and SUBBARAJU, R.C. 1975. Zooplankton of Porto Novo, S.India. ***Bull. Dept. Mar.*** Sri Univ. Cochin, 1975, V11.4. pp 899-91.

SARVESAN, R., THANGAVELU, R., SREENIVASAN, P.V., SUNDARAM, K.S. and POOVANNAN, P. 1988. Edible oyster resources of Ennore estuary and Muttukadu backwaters, Madras. *Bull. Cent. Mar. Fish. Res. Inst., 42:50-57.*

SATHIYAMURTHY, K., LATHA. K. and PURUSHOTHAMAN, A. 1991. Studies on Cu-tolerant bacteria in the Vellar estuary, southeast coast of India. Ind. *J. Mar Sci;.* Vol 20, Sept 1991 pp. 229-231.

SATPATHY, K.K.. VENUGOPALAN, V.P.. NAIR, K.V.K. and MATHUR, P.K. 1990. Environmental and operational problems and their assessment at power plant sites: The Kalpakkam experience. Proc. of *a Natl. Symp. on Envt:* Scientific *approach* to environmental issues. BARC, Bombay. Feb 3-5, 1992, pp. 8-10.

SELVAM, V.. MOHAN, R., RAMASUBRAMANIAM, R. and AZARIAH, J. 1991. Plant communitiesand soil properties of three mangrove stands of Madras coast. *Ind. J.* of *Mar Sci.* Vol 20. Mar 1991. pp. 67-69.

SENGUPTA. R. and QASIM, *S.Z. 1985. The Indian Ocean – An environmental overview realities and prospects.* R.C. Sharma Rajesh. Pub., New Delhi.

SIVASWAMY. S.N. 1990. Plankton in relation to coastal pollution at Ennore. Madras coast. *Ind. J. of Mar. Sci.* Vol. 19. June 1990 pp. 115-119.

SREENIVASAN. A. 1990. Limnological survey of Cauvery river system with particular reference to pollution indicators. *Environmental Research.* Executive summaries of completed projects. Vol.1. Ministry of Envt. and Forests. New Delhi. 43 p.

SUNDARARAJAN, D. and SAMBANDAM, K.P. 1987. Preliminary account on hydrobiology and fisheries of Coleroon Estuary. *Indian J.* Mar. Sci., Vol. IX. 1987. pp. 38-42.

TAMPI, P.R.S. 1969. Productivity of saline lagoon near Mandapam, India. *Proc. Intl. Symp. on coastal lagoons,* UNAM-UNESCO. Nov. 28-30 1967). Mexico, D.F. pp. 485-494.

THANGAVELU, R. and SANJEEVARAJ, P.J. 1988. Distribution of molluscan fauna in the Pulicat Lake. *Bull. Cent, Mar. Fish. Res. Inst. 52:58-67.*

THANGARAJ, *G.S.* 1984. *Ecobiology of rhe marine zone of rhe Vellar Estuary.* Ph.D. thesis. CAS in Marine Biol., Annamalai University, Annamalainagar. 192 p.

WOLSTENCROFT, A.J., HUSSAIN, S.A. and VARSHNEY, C.K. *1989. A Directory of Asian Wetlands.* IUCN pp. 367-505.