Full citation: Bankoff, Greg. "Societies in Conflict: Algae and Humanity in the Philippines." *Environment and History* 5, no. 1 (February 1999): 97–123. http://www.environmentandsociety.org/node/2999.

Societies in Conflict: Algae and Humanity in the Philippines

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SUMMARY

This paper examines the origin and evolutionary role of microalgae, the phenomenon of harmful dinoflagellate blooms commonly referred to as red tides, their history in the Philippines since a regular annual occurrence in 1983, and the loss of livelihood, morbidity and even death caused through the human consumption of seafood contaminated by such toxins.

Historiography has traditionally been concerned with human societies in conflict: conflict between societies over land, people and resources; or conflict within societies over the distribution of power, the control of labour and the ownership of capital. Seldom, however, have historians recognised that other non-human forms of societies exist on our planet, or, if they are sometimes acknowledged, they are loosely referred to as natural history and usually relegated to the sphere of the zoologist and botanist. Yet other forms of societies do exist and compete, by necessity, often in complex and intricate ways with human societies for the same planetary resources. Sometimes this relationship is a symbiotic one, but, at other times, there exists a state of conflict between these societies and human societies.[1]

This paper investigates the nature of one such relationship, the state of conflict that presently exists between some species of microalgae, in the form of harmful planktonic blooms commonly referred to as red tides, and the contemporary human society known collectively as the Republic of the Philippines. In particular, the paper examines the origin and evolutionary role of microalgae, the phenomenon of red tides, the history of toxic dinoflagellate blooms in the Philippines since their regular occurrence in 1983, and the loss of livelihood, morbidity and even death caused through the consumption of contaminated

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seafood as a result of the present conflict that exists between these societies. Finally, in the course of this discussion, the relationship between species competition and historiography is also explored.

Among most historians, there exists an implicit assumption that humanity stands at the apex of life on this planet, while microalgae, as single celled organisms, are regarded as being on the borderline between the plant and animal kingdoms, photosynthesising food sugars from sunlight like the former but able to move by means of whiplike flagella like the latter. Yet these species, human and algae, and the societies they create, seem set on an accelerating course of conflict over coastal waters and their resources. A conflict, moreover, where there has already been substantial human loss in terms of both life and property, and one in which the prognosis for human societies is not particularly favourable.

MICROALGAL SOCIETY

The historical contribution of microalgae extends well beyond their current (and still underrated) role and is central to the development of life on this planet in its present forms. The forerunners of today's genera of microalgae were instrumental in the process begun some 3.5 billion years ago whereby the world was converted from a hydrogen based atmosphere to one in which oxygen predominates. These ancient forms of microalgae photosynthesised sunlight into chemical energy, giving off oxygen as a by-product in much the same way as modern plants do. By some two billion years ago the planet's oceans had become saturated with oxygen which began to bubble up out of the sea and accumulate in the atmosphere, changing its composition. In the process, these organisms committed what Fred Pearce has termed 'collective suicide', changing the entire chemistry of the planet to one which was unsuited to the survival of all but a few of their own kind, and so paving the way for the evolution of new life forms with metabolisms based on the respiration of oxygen, including ultimately humanity (Pearce 1989: 43-44).

Today's microalgal species are descendants of cyanophyceae, blue-green algae that were prolific producers of oxygen but equally able to flourish in the planet's changing atmospheric composition (Pearce 1989: 44). At present, there are some 2,000 species of the marine form of these microorganisms, known as dinoflagellates, inhabiting both boreal and tropical seas (Taylor 1987: 1). They are simple, single-celled organisms (a millilitre of seawater can contain tens of thousands of cells) capable of moving with a whirling motion by means of their unique flagella arrangement that permit them to propel themselves both horizontally and vertically at a maximum rate of about one metre per hour (Tacio 1994) or in excess of 10 metres per day (Anderson 1994: 56). Migrating to surface waters during the day to 'harvest' sunlight, they sink back to lower layers to take up nutrients during the hours of darkness.

Normally, dinoflagellates live in small, scattered communities in the sea, with many species able to remain encysted or dormant in bottom sediment for years when water conditions are not supportive, but also able to reproduce rapidly by asexual fission (simple division) in more favourable conditions of intense sunlight, changing salinity levels and opportune weather conditions such as heavy rains or winds that increase nutrient availability (Spector 1984: 217-218 and Caburian 1988).[2] Many species are capable of doubling their numbers in a day (Pearce 1989: 155). In dense concentrations, these micro-organisms form massive, mat-like colonies or monospecific planktonic blooms that carpet the water's surface, excluding competitors and perhaps even predators (Spector 1984: 220). Often these blooms develop in discrete water masses such as estuarine or nearshore waters, especially former mangrove swamps, where the integrity of the water composition can be maintained for longer (Daiwey 1992 and Spector 1984: 222).

Blooms develop either autochthonously, that is in their area of origin, or allochthonously, developing elsewhere and being transported to another area. Currents and tides act as the 'dynamic transport mechanism' for their dispersal but the actual distribution of dinoflagellates is largely determined by hydrological processes such as the frontal systems associated with current boundaries and upwelling (Spector 1984: 216 and 222). More recently, however, human activities have been identified as having possibly played an important part in expanding the global distribution of microalgal blooms, either through the eutrophication of coastal waters or the transportation of cysts in the ballast tanks of ships (Maclean 1993: 254 and Hallegraeff 1993: 96).[3]

But the role of all microalgae in the current planetary ecosystem is not simply confined to being a basic but important link in the marine food chain. James Lovelock, more famous as the author of the Gaia thesis, also made the important discovery that most species of microalgae excrete dimethylsulphide (DMS) into the atmosphere, a gaseous by-product of the microorganism's need to cope with excess salt in coastal waters and the source of that distinctive seaside smell. According to Lovelock et al., DMS emissions react in the air to form a sulphate and methane sulphonate aerosol, the particles of which act as cloud-condensation nuclei over the oceans, increasing the planet's albedo or ability to reflect sunlight and so maintain moderate temperatures and prevent overheating (Charlson et al. 1987: 655).[4]

Just as significantly, phytoplankton act as one of the planets's most important carbon sinks. Ocean plants have much faster metabolisms than their terrestrial counterparts, feeding on enormous quantities of carbon dioxide dissolved in the water which is processed into proteins and simple sugars, and subsequently stored in the ocean's depths in the form of skeletal remains or excreta (Seguiban 1992: 16-17 and Pearce 1989: 155). According to Roger Ravelle, algae act much as the planet's 'biological pump', helping to mitigate the full impact of global warming or the *greenhouse effect*.

‘MILITANT’ MICROALGAE: TOXIC RED TIDES

These societies, then, composed of countless numbers of microalgae scattered across the oceans of the world, have had, and continue to have, a significant influence on the planet’s ecosystem and so indirectly on humanity. But microalgae and humanity have also had a history of more direct contact in the form of harmful planktonic blooms more commonly known as red tides.

Red tide is the term given to waters in which there has been a prolific multiplication in the number of microalgae so that the sea takes on a red, brown or even green colour from the pigment secreted by the these organisms.[5] Most of these microalgal blooms are harmless and a few have even given their name to some of the planet’s principal bodies of water, most notably in the case of the Red Sea, which takes its name after an innocuous microorganism known as sea sawdust or *Trichodesmium* (Fernandez 1991). Other blooms, however, are far less benign with the discolouration of the water acting as a warning of toxicity.[6]

Some 20 species of dinoflagellates have been found to possess toxic qualities (Maclean 1993: 255 and Spector 1984: 203). The precise number is difficult to determine as improvements in detection and analytical methods over the last 15 years has regularly led to the identification of more toxins and more potentially toxic species.[7] Physiologically, too, there is little difference between toxic and non-toxic dinoflagellates and, even among toxic species, most have similar cytological structures (Spector 1984: 204 and 210). However, the actual cause of toxicity among dinoflagellates remains unclear, though it is suspected that endocellular bacteria or viruses may produce the toxins or at least stimulate their production.[8] Nor is it known whether higher toxicity represents increased toxin production, toxin accumulation or the conversion of existing toxins to more potent ones (Spector 1984: 209).

The toxins produced by these marine microorganisms are among the most potent nonproteinaceous lethal materials known (Spector 1984: 223). Neurotoxins, especially, severely disrupt neurological functions by affecting the semi-permeable lining of nerve cells, blocking the propagation of impulses and causing paralysis (Caburian 1988 and Arafiles et al. 1984: 46). Saxitoxin, one of the most common neurotoxins found in dinoflagellates, is considered to be 50 times more potent than curare and to be dangerous to the human metabolism in dosages of more than 1 microgram (Gonzales 1990 and Arafiles et al. 1984: 46).[9] While it remains unclear why microalgae need to produce such virulent poisons, the toxins themselves enter the food chain by means of transvectors: primary transvectors such as filterfeeders, herbivorous fish and detrital feeders that consume the toxic progenitors directly; and secondary transvectors, primarily omnivores and carnivores, that feed upon the primary transvectors. Many of these transvectors are able to accumulate and store lethal quantities of toxins without apparent harm to themselves (Estudillo et al. 1984: 52 and Spector 1984: 234). Research on secondary transvectors is incomplete, but many filterfeeders, especially shellfish, are known to accumulate in their internal organs toxins which are retained for several months after the red tide has abated.[10]

Until recently, the deleterious feature usually associated with toxic red tides has been the occurrence of extensive fish kills through respiration of waters containing the organism, predation on filterfeeding transvectors or simply, as in the case of birds, drinking the saltwater in bloom areas. Not that tides necessarily have to be toxic to cause fish kill, as collapsing blooms can also precipitate widespread mortality through oxygen depletion of the water (Maclean 1993: 259). While human fatalities have long been identified with this phenomenon, reportedly claiming over 200 lives and some 1,400 victims between 1689-1965 (Spector 1984: 241), the extent and frequency of human intoxification would appear to have markedly accelerated in the last quarter century (Estudillo et al. 1984: 52) and presently accounts for nearly 2,000 cases of poisoning (with a 15% mortality) each year (Hallegraeff 1993: 80).[11]

Human exposure to marine toxins is usually through the consumption of contaminated foods, most commonly shellfish such as mussels, clams and scallops.[12] The manner in which filterfeeders strain organic material from vast quantities of water concentrates toxins in their digestive tracts which are not removed before ingestion. There are four distinct types of marine food poisoning known to be directly attributed to filterfeeders that cause human intoxication: paralytic shellfish poisoning (PSP), diarrhetic shellfish poisoning (DSP), neurotoxic shellfish poisoning (NSP) and most recently amnesic shellfish poisoning (ASP). DSP has largely gastro-intestinal symptoms and is rarely fatal, while NSP, first documented in 1976 among scallop beds in Japan, also triggers diarrhoea and abdominal pains but is accompanied by dizziness and profuse sweating. Little is known about the more serious ASP since its first appearance in Canada in 1987, except that it can cause short-term memory loss and impaired mental processes.[13]

Most serious human intoxication has been caused by PSP, the symptoms of which usually appear within 30 minutes of eating adulterated seafood. Initial paraesthesia to the face and digits is followed, in severe cases, by ataxia or loss of control over muscular movements, a ‘peculiar feeling of lightness, “as though one were floating in air”’, headache, salivation, rapid pulse, intense thirst and perspiration. Other less common symptoms include impairment of vision or even temporary blindness and gastrointestinal manifestations such as nausea, vomiting, diarrhoea and abdominal pain. Death in the event of acute dosage is caused by asphyxiation from paralysis of the respiratory system (Gonzales 1990 and Spector 1984: 241). The toxin from one to three contaminated mussels is said to be enough to kill an adult person and all attempts to produce an antidote have so far been unsuccessful (Hallegraeff 1993: 80; Red Tide 1988 and Estudillo et al. 1984: 52). The first well documented case of PSP took place in 1927 in San Francisco with over 100 cases and 6 deaths (Caburian 1988).

Human knowledge of red tides, however, considerably predates 1927. The first reference to what was undoubtedly a toxic algal bloom is the biblical story of Moses cursing the land of Egypt for Pharaoh's failure to grant the Israelites their liberty: 'And all the waters that were in the river were turned to blood. And the fish that was in the river died; and the river stank, and the Egyptians could not drink water from the river; and the blood was throughout all the land of Egypt' (Exodus 7: 20-21). In the Pacific, Captain Cook observed *Trichodesium* blooms in the Coral Sea in 1770 and Charles Darwin recorded a red tide off the coast of Chile in 1835 (Maclean 1993: 252). Later still, a French priest on New Caledonia, Fr Montrouzier, noted in 1860 that local people reportedly fell ill after eating fish at times when a certain monad coloured the sea red or green for hundreds of metres (Maclean 1989: 306). Red tides, described as 'rivers of blood', are reported to have caused seasonal fish kills in Sydney harbour during the late 19th century (Fernandez 1992). The term, however, was not coined until 1904 when red tides were officially recognised as a marine occurrence (Caburian 1988).

Red tides, then, have occurred throughout recorded history but the extent and frequency of the phenomenon appear to be increasing in recent years. Among others, red tide hit Tampa Bay in Florida in 1947, the Seto Inland Sea of Japan in 1957, the Northumberland coast of Britain in 1968, North America's eastern seaboard and Papua New Guinea in 1972, Spain and Holland in 1978, the east coast of India in 1981, New Zealand in 1984, and Canada, Argentina and Thailand in 1985. In 1987 alone, contaminated shellfish were reported from locations as diverse as Tasmania, Taiwan, Korea, Hong Kong, Guatemala and Venezuela (Zamora 1994; Anderson 1989: 11; Maclean 1989: 305 and Caburian 1988).[14] As well as evidence of an expanding habitat, there are also indications that the number and regularity of red tides is on the increase. Hong Kong, for instance, experienced more than 40 algal blooms caused by 14 different dinoflagellate species between 1980-1983 (Fernandez 1991) or an eightfold increase in the number of red tides each year between 1970-86 (Hallegraeff 1993: 96).

A number of explanations have been suggested for the apparent global increase in the extent and frequency of red tides (Anderson 1994: 52-57 and Hallegraeff 1993: 81). Some deny that there has been any increase, pointing to improvements in scientific knowledge and detection as the main reason for the higher number of recorded incidents in the last quarter century (Anderson 1989: 13). Others refer to changes in coastal ecosystems and the rapid eutrophication of waters from siltation, pollution and deforestation (Anderson et al. 1989: 13-14 and Chua et al. 1989: 335-336 and 341). Still others look for answers in natural phenomena: heavy rains after long dry spells, the advent of the monsoon season and typhoons; or to changing weather patterns like the appearance of warm ocean currents associated with the El Niño-Southern Oscillation Effect (Fernandez 1992 and Maclean 1989: 308) and rises in water temperatures (Zamora and

Gonzales 1992). Most commentators, however, agree that human activity is at least partly responsible for the increasing number of reported algal blooms worldwide. As the late Dr Inocencio Ronquillo, a Philippine fishery expert, wrote in 1987: ‘Deforestation, soil erosion, heavy rains, use of chemical fertiliser beyond normal levels, and other destructive man-made activities added up to the red tide phenomenon’ (Fernandez 1993).

RED TIDES IN THE PHILIPPINES

Toxic red tides were first recorded in the Western Pacific off the Papua New Guinean coast in 1972, causing three fatalities and 20 less serious cases of PSP. They struck again in following years with massive blooms being recorded in the waters off Brunei and Sabah during March-May 1976 when at least seven people died and there were over 200 reported cases of PSP. More cases with further loss of life were reported in 1980, 1983, 1984 and 1988. Red tides are now seasonal events in these waters. In 1983, blooms appeared along the Johor Straits and off Penang in West Malaysia, in East Nusa Tenggara and Flores in Indonesia, and in the inner Gulf of Thailand. Two people died in Singapore after eating contaminated mussels taken from the Seletar River in 1984. By the mid 1980s, then, toxic blooms had become a regular occurrence in much of the coastal waters of Southeast Asia (Tacio 1994, Maclean 1989: 304-307 and Estudillo et al. 1984: 52-59).

Red tides were almost unknown in Philippine waters prior to 1983 but between July and September of that year algal blooms appeared in the Eastern Visayas, affecting over 300km of coastline in Samar and Leyte and extending northwards to Masbate and Sorsogon.[15] Bloom concentration was heaviest in coastal waters, especially near river mouth systems: commercial airline flights even reported one continuous red tide of 70km stretching up the West Samar coast from Villareal to Gandara. In its wake, at least 20 people died, more than 300 were hospitalised and there were approximately 700 cases of intoxication (Giron 1991; Maclean 1989: 306, Estudillo et al. 1984: 56 and Gacutan et al. 1984: 80).[16]

In 1987, red tides reappeared in the Samar-Leyte region but also in the coastal waters off Zambales, some 400km to the north, where harmful plankton blooms were observed between Subic Bay and Santa Cruz causing 6 fatalities and 205 cases of PSP related illnesses (Daiwey 1992; Anderson 1989: 45-47 and Maclean 1989: 306).[17] The following year blooms first appeared in Manila Bay and 61 people were hospitalised and fout died (Maclean 1989: 307). In all, there were seven major incidences of red tide between 1987-89: two in Samar-Leyte in 1987 and again in 1988, the one in Zambales in 1987, one each in Manila Bay, Negros Occidental and Capiz in 1988, and one in Cebu in 1989 with a total of over 1,200 PSP cases and 42 deaths (Giron 1991).

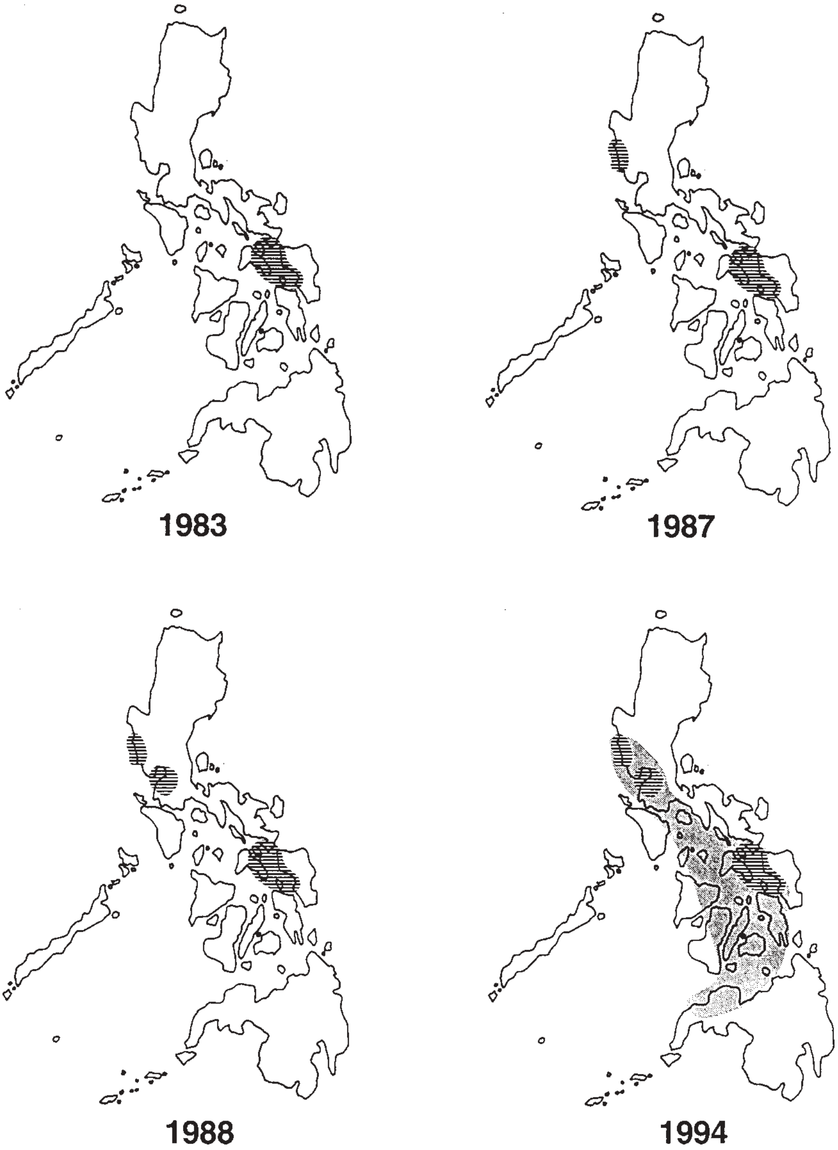

FIGURE 1. The expansion of red tides in the Philippines, 1983–1994

The microalga responsible for these blooms is a species of dinoflagellate identified as *Pyrodinium bahamanese* var. *compressa*, unreported in the Western Pacific prior to 1972 and first described by Plate from samples collected from a shallow, saline lagoon in Nassau, the Bahamas in 1906 (Gonzales 1990 and Estudillo et al. 1984: 52).[18] While not all toxic red tides in the region are due to this species, it has been responsible for most of the toxic blooms affecting the coastal waters of Brunei and East Malaysia since 1980 and for all such events in the Philippines (Chua et al. 1989: 341).[19] *Pyrodinium* cells contain at least five neurotoxins including saxitoxin and gonyautoxin V which together comprise about 85% of the total toxin content (Gonzales 1990). These toxins are very water-soluble and remain unaffected by heat or cooking.

The prime means of human intoxication in the Philippines is through the consumption of contaminated shellfish, especially the green mussel (*Perna viridis*) known locally as *tahong,* but also clams (*halaan*) and oysters (*talaba*). For instance, 67% of the 211 reported PSP cases during the red tide that struck Samar between May-August 1987 were attributable to mussels (Gonzales et al. 1989: 47). The World Health Organisation (WHO) has set a standard of 80 micrograms of dissolved toxin per 100 grams of shellfish as the limit for safe human ingestion of *Pyrodinium bahamenese*, but a growing concern that some

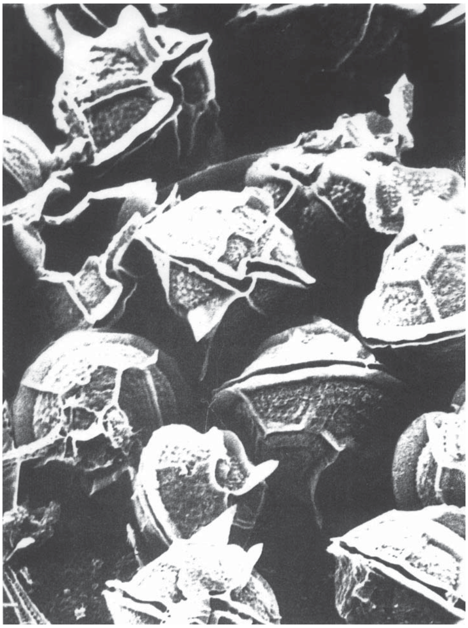

FIGURE 2. *Pyrodinium bahamense* var. *compressa* (extreme magnification)

people, especially the young and old, may be adversely affected at much lower levels of toxicity, led to the standard in the Philippines being lowered to 40 micrograms in 1993 (Lobo 1993 and Red Tide 1992). Recorded toxicity levels in contaminated mussels and other shellfish regularly exceed by up to 16 fold the tolerated maximum set by the WHO and, in one instance the level was nearly 88 times higher (Crisostomo 1992 and Red tide 1992)!

Since 1990, red tides have become a regular annual occurrence in the Philippines with blooms affecting the coastal waters of Zambales and Camiguin Island in 1990, Manila Bay between 1991-1993, Panay and Samar-Leyte in 1992, and Zamboanga del Sur in 1994 (Garafil 1994; Tacio 1994 and Lacson 1992). As of January 1995, toxic dinoflagellates were reported in locations as far apart as Sorsogon, Negros Oriental, Capiz, Zamboanga del Sur and Camiguin Island (Gonzales 1995). Government authorities have responded by monitoring toxicity levels and imposing temporary bans on the harvesting, transportation, sale and consumption of shellfish from affected areas. This has undoubtedly contributed to minimising the rate of morbidity. For example, in Manila Bay there were only 467 documented cases of PSP with 23 fatalities between 1988-1993 despite a population in excess of 10 million (Lobo 1993).

Just what causes *Pyrodinium bahamense* red tides and how the blooms spread within Philippine waters are undetermined as yet, but some interesting and highly suggestive explanations have recently been put forward. It appears that *Pyrodinium* blooms are especially susceptible to natural events and are possibly triggered by changes in weather patterns (Chua et al. 1989: 341).[20] In particular, 'a remarkable coincidence' has been noted between the occurrence of these blooms and the El Niño-Southern Oscillation (ENSO); there certainly appears to be a marked correlation between ENSO events and the occurrence of red tides in the region (Maclean 1989: 308).

ENSO events	*Pyrodinium toxic bloom years*	*Red tide site*
1972-1973	1972	PNG
1976-1977	1976	Brunei/Sabah
1979-1980	1980	Brunei/Sabah
1982-1983	1983	Philippines
1986-1987	1987 & 1988	Philippines

Source: Maclean 1989: 308

TABLE 1. A comparison of El Niño-Southern Oscillation events and major Pyrodinium toxic bloom years, 1972-1988.

If ENSO events create the abnormal conditions favouring *Pyrodinium* blooms, then ocean currents may prove to be the means by which the microalgae have been able to effect a ‘stepwise migration’ throughout the region. After the 1972 Papua New Guinean bloom, dinoflagellates were possibly carried by the Southern Equatorial Current to colonise the coasts of Brunei, Sabah and then the Philippines (Anderson 1989: 12).[21] An increase in the nutrient level of coastal waters may provide sufficient sustenance to allow the microalgae to be carried farther than previously (Fernandez 1992).[22] Other explanations point to the seasonality of red tides in the Philippines, suggesting that the microalgae may be ‘wind-driven’ with the monsoon passing through Sabah, where red tides occur all year round, transporting the *Pyrodinium* northwards (Daiwey 1992). Certainly research conducted by the Department of Health implies that a similar dependence on natural phenomena may operate within the Philippines, with blooms being blown to parts of Bataan by the Southwest Monsoon (Saquin 1992). Even within Manila Bay, there appears to be an established pattern in which the organism strikes at the Bataan side first before appearing off the coastal areas of Parañaque, Las Piñas and Cavite (Lobo 1993).

Whether microalgae have been carried to the Philippines by currents or winds or a combination of the two, or whether *Pyrodinium* cysts have always been present in coastal sediments, their influence on human society has been growing in recent years. No longer can the impact of red tides only be measured in terms of the loss of human life and illness, regrettable as these may be to the families involved: it has now to be assessed also in terms of the economic loss suffered by the living. As toxic blooms affect some of the most productive aquaculture regions of the Philippines, tens of thousands of fisherfolk and their families have temporarily lost both their livelihood and chief source of sustenance. The *states of calamity* declared by President Ramos on 4 July 1992 and 27 July 1993 covering the coastal areas of Metro Manila, Bataan, Pampanga, Bulacan and Cavite were recognition of the enormous hardship being experienced by marginal fisherfolk in Manila Bay and of their pressing need for assistance from public funding (Suarez 1992; Zamora and Gonzales 1992 and Lobo 1993).

SOCIETIES IN CONFLICT

So far this paper has documented a phenomenon: the development of red tides or toxic microalgal blooms, the apparent global increase in the extent and frequency of such events, and their specific expansion into Philippine waters. But there has also been an underlying assumption that these microalgal species constitute societies with their own biological imperatives and properties as distinct as those of human ones. While there has been a long history of interaction between the two, there seems little doubt that recent human activities associated with the creation of urban industrial economies have severely upset the stability of the previous relationship and intensified the level of competition and conflict. The chief casualties in this contest, as usual, are proving to be the poor and dispossessed of the developing world who are losing both their livelihoods and their lives.

The nature of the conflict between humanity and algae largely takes place where the two societies meet, at the border between their respective elements of land and water. The effectively unrestrained use of coastal waters in the developing (and developed) world to dump the waste and by-products of industrial societies on the one hand, and the inexorable search for cheaper and cheaper sources of protein to feed burgeoning and increasingly impoverished populations on the other, create the conditions in which red tides flourish and the consumption of shellfish rises.

The pollution of Philippine coastal waters mainly takes place in one of three ways: the disposal of organic and non-organic human sewage; discharges from industrial, agricultural and aquacultural ventures; or run-off caused by widespread deforestation. The scale and extent of all these activities have increased markedly since the Philippines gained independence in 1946, and especially since the 1960s.

Approximately 25 million or 43% of Filipinos live in urban areas, none of which have efficient sewage collection or treatment systems. Worst of all is Metro Manila with its more than 7 million inhabitants, a population density of 8,395 persons per square kilometre expected to rise to over 15,000 by 2000, and a rate of demographic increase estimated at 3.6% annually (Philippine Strategy 1991: 17 and Macaspac 1988). Only 12-13% of the capital's inhabitants have any form of sewerage system, the main portion of which was constructed between 1904-1911 for a population of 220,000 but is currently servicing 530,000 people (Philippine Strategy 1991: 17-18 and Macaspac 1988).[23] In most cases, untreated domestic sewage is simply discharged directly into the main water-courses where it accounts for approximately 60-70% of all biodegradable organic pollutants (Franco 1991 and Philippine Strategy 1991: 17-18). Moreover, the capital generates 3,600 tons of municipal and solid refuse daily, much of which also finds its way into the river system through open canals and culverts. Finally, at least 25% of the population live in squatter settlements or slums, many of which are in low lying areas along creeks or *esteros* that flood during the rainy season causing wastes from privies and septic tanks to overflow into open drainage canals and ditches (Saquin 1992 and Macaspac 1988).

While domestic sewage comprises the major source of pollutant in water-courses, the other 30-40% of waste material is composed of industrial and chemical discharges from industry, mining and agriculture. There are reportedly as many as 17,000 firms located along the 15km banks of the Pasig River that collectively discharge some 11 million gallons daily of untreated or only partially treated industrial waste water into Manila Bay (DEPTHnews 1992 and

Macaspac 1988). In Samar and Cebu, the practice of large mining corporations includes the dumping of tailings into the Taft River or directly into fishing grounds, while the run-off of petroleum-derived fertiliser and pesticide residues used in agriculture is yet another significant source of pollution (Giron 1992). Even aquaculture, traditionally practised in Southeast Asian waters for over 500 years, has reached such a scale and intensity in recent years as to be having a negative impact on coastal ecosystems. The promotion of aquaculture as an alternative to depleted coastal fishing has encouraged the clearance of mangrove and other wetlands to accommodate new fishponds, and has led to alterations in the hydrological regime of small coves and bays by increasing siltation (Chua el al. 1989: 335-336).[24] Some scientists predict that the value of world aquacultural production will equal that of the 'wild' catch by 2010 (Hallegraeff 1994: 83).

The scale of non-point source run-off and soil erosion due to widespread deforestation has also significantly increased recently since the adoption of economic policies in the late 1960s favouring export oriented industrialisation.[25] Currently the Philippines has 16.5 million hectares or 55% of its total area legally classified as forest land, but the actual extent of forest cover in 1991 was 6.5 million hectares. Moreover, remaining forests are being felled at the rate of 119,000 hectares annually, equivalent to approximately 14 hectares per hour, from logging operations, fire and swidden agriculture. Loss of forest cover has made soil erosion a serious problem in 21 provinces where over 9 million hectares of alienable land are affected to varying degrees and a further 1 million hectares of agricultural land on hillsides are susceptible during the rainy season (Philippine Strategy 1991: 15 and 21).

The sheer volume of this organic, mineral and sedimentary discharge causes the eutrophication of significant sections of Philippine coastal and estuarine waters and so creates the conditions favouring microalgal blooms. The presence of certain nutrients also appears to stimulate the growth of dinoflagellates, with cobalt in the form of cyanocobalamin, nitrogen as ammonium or urea, and the phosphorus supplied by decaying organic matter all suspected of playing an important role in causing red tides. At the same time as the waste and by-products generated by urban industrial societies create the conditions supporting the proliferation of toxic microalgal blooms, the nutritional requirements of ever increasing human populations, and the maldistribution of resources within those same societies, give rise to a demand for cheaper and cheaper sources of protein that is currently being satisfied by seafood (Spector 1984: 240). The recent growth in the Philippines' consumption of mussels, not traditionally considered a seafood dish, can be explained as meeting a need for a relatively low-priced source of protein for the poor and impoverished (Arafiles et al. 1984: 43).

While shellfish in general and mussels in particular may be a cheap source of protein, their harvesting and/or cultivation also provides tens of thousands of marginal fisherfolk and those in related occupations with the actual means of making a livelihood. Toxic red tides and the bans imposed on the sale and transportation of shellfish deprive many of the poor, not only of the food on their tables, but also of the means of putting it there too. Moreover, the entire domestic pelagic and demersal fishing industry suffers: as the demand for all but freshwater fish falls, their price plummets and even exports markets are affected.

The extreme plight to which marginal fisherfolk can be reduced is exemplified in the case of Freedom Island, 45 hectare of land reclaimed from Manila Bay with a population of 15,000 residents, most of whom are dependent upon the collection of mussels both as food and as a commodity to sell. By 1992, fisherfolk on the island were experiencing their third consecutive season of red tide with its consequent loss of income. Most families had pawned almost everything of value that they possessed and, despite the presence of algal blooms in the Bay, were forced to depend on crustaceans and invertebrates to feed their families. One fisherman described testing the crabs he caught on the cat first, throwing away what the animal refused to eat (Evangelista 1992).

Nor is the distress simply confined to marginal mussel and shellfish collectors, but red tides affect the entire fishing industry. The mass hysteria engendered by media reports of PSP cases inevitably depresses the demand for all marine products; consumers indiscriminately avoid buying any seafood despite evidence that most species are largely unaffected by the toxin and safe for human consumption. The appearance of red tide in Manila Bay in 1988 caused the price of saltwater fish in the capital's principal fish market at Navotas to tumble from between P800-1,000 (US$32-40) a basin to only about P200 (US$8) (Red Tide 1988). Even in 1991 and again in 1992, when toxic blooms had become a regular seasonal occurrence in Philippine waters and information about them more widely disseminated, the sale of deepwater fish such as *galunggong*, *alumahan*, *alimango*, *matambaka* and *tamban* dropped by as much as 50% and prices per basin were halved (Cortes et al. 1992; Diaz 1992 and Perez 1991). Some newspapers even reported that the price of *alimango* and *alumahan* fell from P70 (US$2.80) and P55 (US$2.20) respectively to P20 (US$0.80) (Perez 1991), while the price of *galunggong* in Manila's Divisoria market dropped from P40 (US$1.60) to only P10 (US$0.40) a kilo (Alibutud 1992). In many cases, fish were just left to rot on the market stall with the perennial electricity shortages even preventing their preservation through refrigeration (Luna and Calalo 1992).

The scale of this suffering in human terms can be gauged by the number of families affected by temporary or permanent loss of occupation and the sharp fall in the number of fisherfolk in certain areas over recent years. A 1988 report estimated that as many as a million fisherfolk and their families around Manila Bay were forced out of work by the scare of poisoning and the ban on shellfish sales (Alvior 1988). Red tide reportedly affected between 12,500-25,000 families in the coastal areas of Metro Manila, Central Luzon and the Southern

Tagalog Region in 1992 (Capco 1992, Santos 1992, and Zamora and Gonzales 1992). Other estimates were higher still: that 18,633 families were affected in Cavite province alone and that some 30,000 fishermen and vendors were economically displaced by the ban imposed on shellfish between June-September 1992 (Cavite families 1992 and Lacson 1992). The main association of small-scale fisherfolk, NACFAR (Nationwide Coalition of the Fisherfolk for Aquatic Reform), declared that overall between 80,000-100,000 fishermen in the cities and provinces around Manila Bay had been affected by the 1992 event (Red Tide 1992).

By 1993, the decline in the number of people working in fishing-related industries had been substantial with some, albeit rather sensationalised, accounts reporting a reduction from approximately 10 million persons nationwide to 350,000 in only a decade.[26] Nor was the reduction across the board, but varied considerably from area to area. In some places, like Parañaque where numbers fell from 200,000 persons to only 50 families, fishing virtually ceased to be a significant occupational activity. In others, fishing remained an important means of making a livelihood but for far fewer: there were only 6,000 fisherfolk in Bulacan in 1993 where 5 years previously there had been 35,000. Still other areas, usually furthest away from the flow of organic and industrial waste, manage to retain a viable fishing industry, at least for the present (Villa 1993).[27]

The economic repercussions for Philippine society as a whole, as well as for individual families of fisherfolk, were no less dramatic. The 1992 red tide in Manila Bay and consequent decline in sales, was estimated to have cost P360 million (US$14.4 million) over a 2 week period in May, comprising some 685 tons of fish a day worth P27.4 million (US$1.1 million) caught by over 121,000 small and marginal fishermen (Diaz 1992). The scare also impacted upon many small fish vendors who lost almost their entire capital as fish remained unsold on market stalls (Alibutud 1992). In all, there was a decline of some 50% in the average income of fisherfolk in Manila Bay, most of whom already lived substantially below the poverty line, earning a mere P700-800 (US$28-32) a month (Red Tide 1992).

Nor did the economic impact of red tides remain confined to the fishing community alone; it influenced the lives of the wider society, especially the urban poor. As demand for all marine products fell away following media reporting of PSP cases, the market mechanism inexorably came into play, forcing up the price of alternate sources of protein. The cost of pork, poultry and other meat products escalated between June-August 1992, at a time of year when prices usually fell, as demand rose and retailers profiteered from PSP reports.[28] Pork rose from P58 (US$2.30) to P86-88 (US$3.45) a kilo and chicken from P62 (US$2.50) to P82-84 (US$3.30) (Cruz 23 June 1992). Congress was concerned enough to pass a bill (Republic Act No.7581) on 27 May permitting the prosecution of price manipulators and their imprisonment for 5-15 years with fines of from P5,000 (US$200) to P2 million (US$80,000) (Ibid.). The following month, a presidential proclamation granted the government power to regulate meat prices which ‘have gone up exorbitantly as unscrupulous traders have taken advantage of the situation’ (Suarez 1992). However, the price of pork in Zamboanga del Sur still reportedly rose from P50 to P65/70 (US$2 to US$2.60/2.80) a kilo in a month after a red tide scare in that province in 1994 (Garafil 1994).

Finally, the economic costs of red tides can also be measured in terms of the loss of exports to the national economy. Despite the scientific evidence that crustaceans are mainly safe for human consumption, even if taken from red tide infected waters, a certain nervousness persists about the flesh of shrimps and prawns, fuelled by the periodic report of PSP cases directly attributable to the local filipino custom of eating deep fried shrimp heads with their beer as *pulatan*. Japan and Singapore responded to the outbreak of red tide in Manila Bay in 1988 by banning shrimp imports with the potential loss of US$500,000 a day if the produce could not be sold elsewhere (Maclean 1993: 182). Another estimate placed the cost to the shellfish industry at P50 million (US$2 million) without any consideration of deep sea fisheries already severely affected by a fishing dispute with Malaysia which was costing the industry millions of dollars (Red Tide 1988).

So far this paper has explored the nature of the conflict between humanity and microalgae in terms of loss of livelihood, loss of sales and even loss of exports. Ultimately, however, the price of this competition has to be measured in terms of the loss of human life. There have been nearly 1,000 documented cases of PSP and at least 51 deaths in the Philippines between 1983-1993 (see Table 2). These figures, however, are likely to be conservative estimations of the actual number of people affected by red tides. The real extent of morbidity is always liable to be minimised by the lack of a ‘systematic analysis of the true cause of death and the unavailability of accurate reports on the affected areas’ (Arafiles et al. 1984: 43).

The dependence of marginal fisherfolk, their families and the urban and coastal poor in general on shellfish as a cheap source of protein inevitably means that most PSP cases and fatalities are drawn from these sectors of society. More detailed analysis of the demographic data also reveals that a disproportionate number of the victims are children, whose smaller body size presumably makes them especially susceptible to the effects of the toxin. Children under 16 years of age, 10 of whom were under 10 years of age, accounted for 11 of the 14 reported deaths where the age of the deceased was known in 1983 (Estudillo et al. 1984: 76). Again, during the 1992 red tide, the Department of Health noted that children between the ages of 3-12 years accounted for most of the 8 deaths recorded by the end of June (Castro 22 June 1992).

*Year**	*Total cases*	*Poisonings*	*Fatalities*
1983	278	257**	21
1987	211	205	6
1988	98	93	5
1991	69	60	9
1992	259	250	9
1993	21	20	1
Total	936	885	51

* There were no reported deaths attributed to PSP for the years 1984-86 and 1989-90.
** Maclean suggests a figure of approximately 700 PSP cases

Sources: Rufo 1993; Lacso 1992; Gonzales et al. 1989:47; Maclean 1989:306 and Estudillo et al. 1984:55.

TABLE 2. Number of reported cases of Paralytic Shellfish Poisoning in the Philippines 1983-1993

Regardless of age, even culinary tastes and habits seem to put certain sectors of the population more at risk than others. Cooking has no effect on the toxic properties of the red tide organism but evidence shows that the potency of the various neurotoxins are enhanced in acid (Gonzales et al. 1989: 47). Much of traditional Filipino cuisine involves the use of vinegar as a cooking medium or as a sauce. Shellfish are often prepared in this fashion or dipped in vinegar immediately before eating, thus increasing the strength of the toxin by as much as 15-fold (Alibutud 1992). The virulent effect of acid is demonstrated in the case of five families from Roxas City in September 1983 who all ate Asian moon scallops caught by the same trawler but cooked them in different ways: either boiling, broiling or using vinegar. None of those who consumed the boiled or broiled scallops exhibited any symptoms of PSP, while those who ate scallops cooked in vinegar fell ill, and one 5 year old boy died (Gonzales et al. 1989: 48). The situation in the Visayas is even more acute as traditionally fish there are cooked without removing their internal organs, thus rendering potentially lethal marine produce usually considered safe for human consumption (Javier 1992). These culinary techniques are more prevalent among the less well-educated and poorer sectors of Philippine society, who disproportionately suffer the consequences.

HUMAN RESPONSES

Human society in the Philippines, of course, has not simply been a passive bystander in the escalating competition with dinoflagellates over the use of coastal waters. Government, communities and individuals have all taken steps to reduce the conditions that precipitate red tides in the first place or to alleviate their impact. The effectiveness of these measures, however, has generally been hampered by the contradictions and divisions with which Filipino society itself is riven: the profit motive, the inability to enforce legislation, and the disempowerment of the principal classes affected.

The Philippines is a developing country with a large and expanding population, limited natural resources and a recent history of endemic political instability.[29] Authorities tend to be reluctant to take any actions that may curb economic growth or to restrain existing industries until forced to by domestic or international pressure. The threat red tides pose to human life was immediately apparent in 1983, but the Marcos government's apparent inability to respond effectively to the situation led at least one commentator to note that the profits obtainable from shellfish beds 'may be given prime consideration even to the detriment of the consuming public' (Arafiles et al. 1984: 43). Nor have official attitudes changed much if the actions (or inaction) of the subsequent Aquino and Ramos administrations are any indication.

On the surface, a comprehensive system for monitoring red tide affected areas has been in place since 1984 and involves aerial surveillance by the Philippine Air Force, the prompt issuing of public warnings and weekly bulletins, the imposition of temporary bans on shellfish from contaminated waters, and the dissemination of information at the municipal level through public meetings, educational seminars and village criers (Giron 1991).[30] The whole monitoring system breaks down, however, because the only facility equipped to carry out a mouse bioassay to test for toxicity in shellfish is located in Manila and results may not be obtained for a week or even longer and then have to be passed on to often remote coastal communities.[31] For example, the BFAR identified red tide in Manila Bay as early as May 1991 but fishermen interviewed in Bataan claimed not to have heard about the bloom till July (Villadiego 1991). The consequence of this delay is that usually several people die before the cause of death is associated with PSP (Arafiles et al. 1984: 43).[32]

Also economic pressures on developing countries may preclude governments from adopting expensive pollution control strategies or of enforcing those already legislated. Under-Secretary Ben Malayang admitted before a Senate public hearing in August 1993 that the Department of Environment and Natural Resources (DENR) simply did not have the budget with which to enforce anti-pollution laws in the Philippines (Pastor 1993).[33] A case in point was brought to the attention of the media by Senator Blas Ople, of an alcohol distillery in Apalit, Pampanga, that had simply continued to operate despite a closure order issued by the DENR for violation of pollution laws. Ople concluded with the observation that ‘pollution not only kills fish but also wrecks the lives of the poor’ (President urged 1993).

Even when laws are passed with the intention of protecting the livelihoods of the poor and powerless in society, opposition from entrenched interests can be intense. The decision to reserve coastal waters up to 15kms for non-commercial fishing vessels less than 3 metric tons and to oblige municipal councils to grant marginal fisherfolk preferential rights to those waters free of charge was bitterly opposed at a committee stage of the 1991 *Local Government Code*. Congressman Jaime Chiongbian of South Cotabato insisted that a requirement to hold a public bidding be inserted into Section 149 of the Code before determining who should be granted exclusive fishing rights in municipal waters (Pimental 1993: 269-270). The compromise eventually reached still disadvantages marginal fisherfolk who sometimes have to bid against wealthy fish merchants for such rights.

The general indifference and/or ineffectiveness of government and communities has forced those individuals most affected by red tide, the small and marginal fisherfolk, to take measures for their own protection through collective action and practical self-help schemes. The Nationwide Coalition of Fisherfolk For Aquatic Reform claims a membership of 600,000 members, an enormous potential pressure group even by Philippine standards. On 28 August 1991, 500 NACFAR members marched on Mendiola Bridge, petitioning Congress to provide relief for some 36,000 fisherfolk currently affected by red tide and to ensure the strict enforcement of anti-pollution laws in Manila Bay (Villadiego 1991).

The national programme of action advocated by NACFAR calls for the creation of a P20 million (US$800,000) fund to develop alternative livelihood projects for displaced fishermen such as duck and livestock farming, the reafforestation of mangrove areas, and the establishment of resource management councils to better oversee water management practices, fishery laws and pollution control (Castro 20 June 1992; Perez 1991 and Villadiego 1991). NACFAR was also a principal proponent in urging President Ramos to declare a state of calamity in 1992, so releasing public funds for the assistance of fishermen affected by red tide and the subsequent slump in sales of all marine products (Red Tide 1992 and Suarez 1992).

Finally, it is also these fisherfolk and their families who, on their own initiative, have taken practical measures to alleviate the effect of toxic blooms in coastal fisheries. Some marine biologists claim that seaweed (*Gracilaria*) successfully competes with microalgae for the organic wastes and fertilisers in seawater and so deprives the dinoflagellate of the nutrients necessary to make them bloom (Villadiego 1993). One proposed long term solution seriously advocates planting extensive seaweed beds along the coasts, an action already spontaneously being undertaken by fisherfolk in Bataan (Villadiego 1993 and

Javier 1992). Ultimately, however, individuals, despite the importance of their contribution to the microenvironment, do not have the necessary resources to contend with the scale and scope of toxic red tides, which requires the effective intervention of the wider community and government.

CONCLUSION

Despite the contradictions and inequalities which accentuate the divisions within human society, that is class struggle, the nature of the conflict surrounding red tides in the Philippines is also, at the systems level, one of competition between species, microalgae and humanity, over the use of natural resources in coastal waters. There is always the danger in anthropomorphising natural phenomenon that the image obscures the intent, and that reality takes on the properties of fiction. Yet competition between species does exist and is no less real for being cast in terms of conflict.

Human activity associated with urban industrial development, and the unequal distribution of resources within societies as a consequence of that development, creates the conditions in which microalgal blooms become endemic and the demand for cheaper sources of protein becomes more imperative. In the case of the Philippines, the seasonal appearance of toxic red tides and the rapid proliferation of the dinoflagellate species *Pyrodinium bahamanese* since 1983 can be attributed to the eutrophication of coastal waters by the nutrients contained in human sewage, industrial discharge, organic and non-organic fertilisers, and the run-off from widespread deforestation. Similarly, the rising cultivation and consumption of shellfish, especially mussels, can be explained in terms of the need to find alternative sources of nourishment for a society growing rapidly both in total numbers and in disparities of wealth.

That it is the impoverished, dispossessed and defenceless of human society who are the principal casualties of this conflict is only to be expected in a world economic system that frequently values increasing productivity over human life. Marginal and small-scale fisherfolk, their families, and the urban poor are the ones who are losing their livelihoods, falling ill and even dying from the effects of toxic blooms. Successive Philippine governments and those whom they serve are generally more concerned with promoting economic development and protecting their own class and sectoral interests than worrying overmuch about the consequences of environmental degradation – unless, of course, it adversely affects economic performance or threatens their investments.

Nor is the prognosis for the future particularly hopeful, according to Jay Maclean of ICLARM. If the eutrophication of coastal waters is a determining factor stimulating toxic red tides, then he suggests one of three scenarios is possible, depending on whether enrichment levels decrease, are contained, or increase. If the level of eutrophication decreases, then algal blooms may revert to being composed of more benign species of dinoflagellate with only the occasional toxic event causing extensive initial loss of life and property as a result of lapsed monitoring activities. If, on the other hand, eutrophication is contained at its present level, then a high degree of unpredictability concerning the species of microalgae involved and the severity of outbreak is to be expected requiring continuous monitoring, and resulting in occasional loss of life and uncertain returns from aquaculture activities. If the level of eutrophication increases, the most probable circumstance, then one or two species of toxic dinoflagellates are likely to become dominant, making the consumption of shellfish hazardous and most coastal aquaculture uneconomic (Maclean 1993: 275). In none of these possible scenarios, however, are red tides likely to vanish from Philippine waters altogether.

Finally, to return to the notion of interspecies competition and whether it has a place in modern historiography. Considering human activity in relation to the various species that share a planetary ecosystem rather than in species specific isolation, permits the historian to ask new questions of the past and glimpse new potentialities in the future. Let me conclude this study of the current relationship between microalgae and humanity in the Philippines by venturing into what some would claim is properly the realm of science fiction rather than the historian’s craft. Scientists have revealed the crucial role played by primordial forms of microalgae which, in the process of converting the planet’s atmosphere from a hydrogen based one to one composed predominantly of oxygen, created a world that was unsuited to the survival of most of their own genera, but which generated the conditions for the evolution of new forms of life that were to succeed them. Maybe it is the role of the historian who attempts to close the gap between natural and human history to speculate on the future of a species that, through its numbers and activities, is transforming an oxygen-based atmosphere into one that will be composed predominantly of carbon dioxide and other gases unsuited to its own metabolism. There is obviously a vast difference in terms of the potentialities of action between a single-celled monad and a human being at the level of the individual, community and even society. But at the species level, it seems that humanity still acts more or less in an instinctive manner akin to that of microalgae.

NOTES

[1] I use the term *society* in this context to refer to the state or condition of living in association with others of the same species for the purposes of mutual benefit.

[2] Heavy rains such as those associated with monsoons increase the supply of nutrients in seawater from terrestrial run offs or river flows, while weather disturbances cause nutrients stored in lower marine waters to be brought to the surface by upwelling (Daiwey 1992 and Caburian 1988). However, it is not easy to generalise about favourable conditions for dinoflagellate growth as it varies substantially for different species.

[3] Dinoflagellate cysts have been found in up to 40% of the ballast tanks of modern shipping that are usually flushed before loading cargo (Rosales 1993: 17). In one instance, more than 300 million cysts were found in the tanks of a single vessel (Hallegraeff 1993: 96). Australia is one of few countries to have issued strict guidelines on the discharge of ballast in coastal waters (Anderson 1994: 58), though, as of 1 November 1991, the International Maritime Organisation introduced voluntary guideline procedures for bulk cargo vessels.

[4] Lovelock et al. go on to suggest a link between biota and climate, with algae increasing DMS emissions to reduce temperatures, as the clouds serve 'as do white daisies in the "Daisyworld" model of Gaian climate regulation' (Charlson et al. 1987: 660-661).

[5] As Anderson points out, however, the terminology can be misleading as 'many toxic events are called red tides even when the waters show no discoloration. Likewise an accumulation of non toxic harmless algae can change the color of ocean water' (1994: 52).

[6] A warning that the indigenous peoples of North America apparently well understood as, according to Rachel Carson (*The Sea Around Us,* 1951): 'For generations before the white men came, the Indians knew this. As soon as the red streaks appeared in the sea and the waves began to flicker at night with the mysterious blue-green fires, the tribal leaders forbade the taking of mussels until these warning signals should have passed. They even set guards at intervals along the beaches to warn the inlanders who might come down for shellfish and be unable to read the language of the sea' (Cardenas 1991: 38-39).

[7] There are even indications that some microalgal species are evolving new strains of toxin, while others, once considered harmless, are developing potent poisons (Rosales 1993: 17).

[8] It has also been suggested that toxicity may either be a self-defence mechanism against microalgal species' main predator, zooplankton, or that toxic compounds have a specific (but as yet unidentified) biochemical role in such organisms' metabolisms (Anderson 1994: 56).

[9] Saxitoxin's complex chemical structure, $C^{1}OH^{1}7N^{7}O^{4}.2HCI$, took biochemists at Berkeley 10 years of research to unravel and is named after a genus of butter clam, *Saxidomus*, from which the poison was extracted (Caburian 1988). The saxitoxins that cause morbidity and even mortality, however, belong to a family of at least 18 different compounds sharing very similar chemical structures and effects (Anderson 1994: 55). The minimum lethal dose for humans is 7 to 16 micrograms per kilo of body weight (Ibid.: 55).

[10] Other known transvectors of toxins apart from shellfish include: Indo-Pacific mackerel (*Rastrelliger brachysoma*), sardines (*Sardinella spp.*), Indian mackerel (*Rastrelliger kanagurta*), crevalle (*Selaroides spp.*) and anchovies (*Stolephorus spp.*) among pelagic fish; slipmouth (*Leiognathus spp.*), threadfin beam (*Nemipterus spp.*), goatfish (*Upenoides spp.*), trigger fish (*Balistes spp.*), whiting (*Sillago spp.*), grouper (*Epinephelus spp.*) and barracuda (*Sphyraena spp.*) among demersal fish (Estudillo et al. 1984 68-69).

[11] Humans are not the only mammals to fall victim to such poisoning as mortality among whales, porpoises and manatees has also been attributed to such harmful blooms (Anderson 1994: 55 and Hallegraeff 1993: 80).

[12] Contaminated water droplets can also be a minor source of human intoxification as the spindrift of waves may cause respiratory and skin disorders reputedly as far as 64kms inland (Cardenas 1991: 39 and Spector 1984: 241).

[13] ASP has been associated with tetrodotoxin, the most potent of all poisons, found in puffer or globe fish and able to cause paralysis of the respiratory muscles within seconds (Zamora 1994). Some of the 100 or so survivors from the Canadian episode had still not

recovered from their short-term memory loss in 1993 (Rosales 1993). The toxin in this case was caused by a diatom and not a dinoflagellate (Hallegraeff 1993: 83).

[14] The geographical range of particular dinoflagellates varies from species to species, with some having a global distribution (*Amphidinium carterae*, *Dinophysis fortii*, *Prorocentrum lima* and *Alexandrium tamarense*), while others are restricted to tropical waters (*Gambierdiscus toxicus*), or even certain geographical areas (*Ptychodiscus brevis*) (Spector 1984: 204). The principal microalgal species commonly identified with toxic red tides include *Gyrodinium aureoleum* off the coasts of Northern Europe, *Ptychodiscus brevis* in the Caribbean, and *Pyrodinium bahamense* in the Western Pacific (Cardenas 1991: 38-39 and Shimizu 1989: 20). Nor are all tides necessarily red: the aquaculture off North America’s New England coast was devastated by the dense blooms of a brown tide in 1987 caused by a previously undescribed species, *Aureococcus anorexefferens* (Anderson 1989: 11 and Shimizu 1989: 20).

[15] There is the evidence, however, of Deputy Commissioner Dr H.M.Smith of the US Fish Commission Steamer *Albatross* dispatched to investigate the reporting of massive fish kill off Bataan in 1908. While Smith dismisses the idea that the mortality was related to the dumping of waste from the US Sanitary Barge *Pluto*, as the complainants had suggested, he does note the presence of dense masses of microalgae that caused a reddish discolouration of the water, its unusual phosphorescence, and the conspicuous absence of fish and bird life (Smith 1908: 187-8). More recently, a joint research project conducted by the Japan-Republic of the Philippines Research Project on Toxic Red Tides has uncovered evidence of toxic dinoflagellate cysts in seabed sediment dating from 1917 in Masinloc Bay, Zambales (Gonzalez 1995).

[16] These are only reported cases of PSP; the actual number of persons intoxicated is likely to be considerably higher as many of the areas affected were remote coastal locations on which statistical data is often incomplete or unreliable (Daiwey 1992).

[17] Jay Maclean speculates that there might have been sub-surface blooms of *Pyrodinium bahamense* in the Samar-Leyte area between 1983-1987 (1989: 306).

[18] The microalga had previously been restricted to the Caribbean, Eastern Pacific Ocean, Red Sea, Persian Gulf and North Atlantic where it was reported to be non-toxic (Estudillo et al. 1984: 52).

[19] For example, *Alexandrium cohorticula* was identified as the species responsible for the toxic bloom in the Gulf of Thailand in 1983 (Chua et al. 1989: 341).

[20] As opposed to other species of toxic dinoflagellates such as *Alexandrium* the blooms of which are more associated with deteriorating water quality (Chua et al. 1989: 341).

[21] An alternate explanation holds the Northern Equatorial Current accountable for the dinoflagellates spread from Palau (Arumizu Bay) to Philippine waters (Estudillo et al. 1984: 65).

[22] There is speculation that the appearance of *Pyrodinium* blooms in Champerico, Guatemala in 1987 originated in the Philippines (Anderson 1989: 12-13).

[23] Rafael Macaspac estimates that sewerage serves 22% of the population but only 9% of the metropolis’s total area (1988) but my own conversations with relevant officials corroborate the lower figure.

[24] An example often cited to support the connection between red tides and aquaculture is Balete Bay in Davao Oriental where PSP was first recognised just one year after the introduction of commercial mussel (*Perna viridis*) culture (Anderson 1989: 14). Maclean, however, contends that, while the evidence is ‘sometimes persuasive’ in the Philippines case, the ‘larger picture’ does not support the association (1993: 273-274).

[25] Export oriented industrialisation policies, dismantling tariff protection of domestic industries and providing incentives for foreign investment, were introduced during Ferdinand Marcos' first term as president post 1966, later consolidated under the political framework of martial law in 1972, and remained fundamentally unchanged till today under his successors, Presidents Aquino and Ramos (Vos and Yap 1996: 146-183; Boyce 1993, and Bello et al. 1982: 127-181).

[26] These figures are contested by Jay Maclean, Director of Information at the Manila based International Center for Living Aquatic Resources Management (ICLARM), who in 1993 estimated that only 7 million people at most were involved in fishing-related activities.

[27] Bataan, for instance, still supported an estimated 50,000 fisherfolk in 1992 (Villa 1992).

[28] The Director of the Bureau of Animal Industry, Romeo Alcasid, reported no supply problems to meet 'normal demand' at the time (Cruz 1992).

[29] The Philippines does have substantial reserves of chromite and cobalt and is a significant producer of copper, nickel and silver.

[30] The coastal watch system established in Luzon and the Visayas during the 19th century to warn of moslem slavers from the south provides an interesting historical parallel.

[31] A new test kit for detecting the toxicity of shellfish that can be carried out by fishermen on location is being developed by the Marine Science Institute of the University of the Philippines and involves injecting *bangaw* or blowflies (*Chrysomya megacephela*) with extracts from tahong (SandT Media Service 1991).

[32] In contrast, the Norwegian Ministry of Environment issues regular 'algal forecasts' based on weekly observations from fish farmers and readings on water clarity and microalgal concentrations from instruments moored at sea (Anderson 1994: 54).

[33] The entire operational budget of the DENR in 1993 was only P3.7 billion (US$148 million) and the proposed budget for 1994 P4.6 billion (US$184 million) (Pastor 1993).

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