Black Pearls and Red Tide

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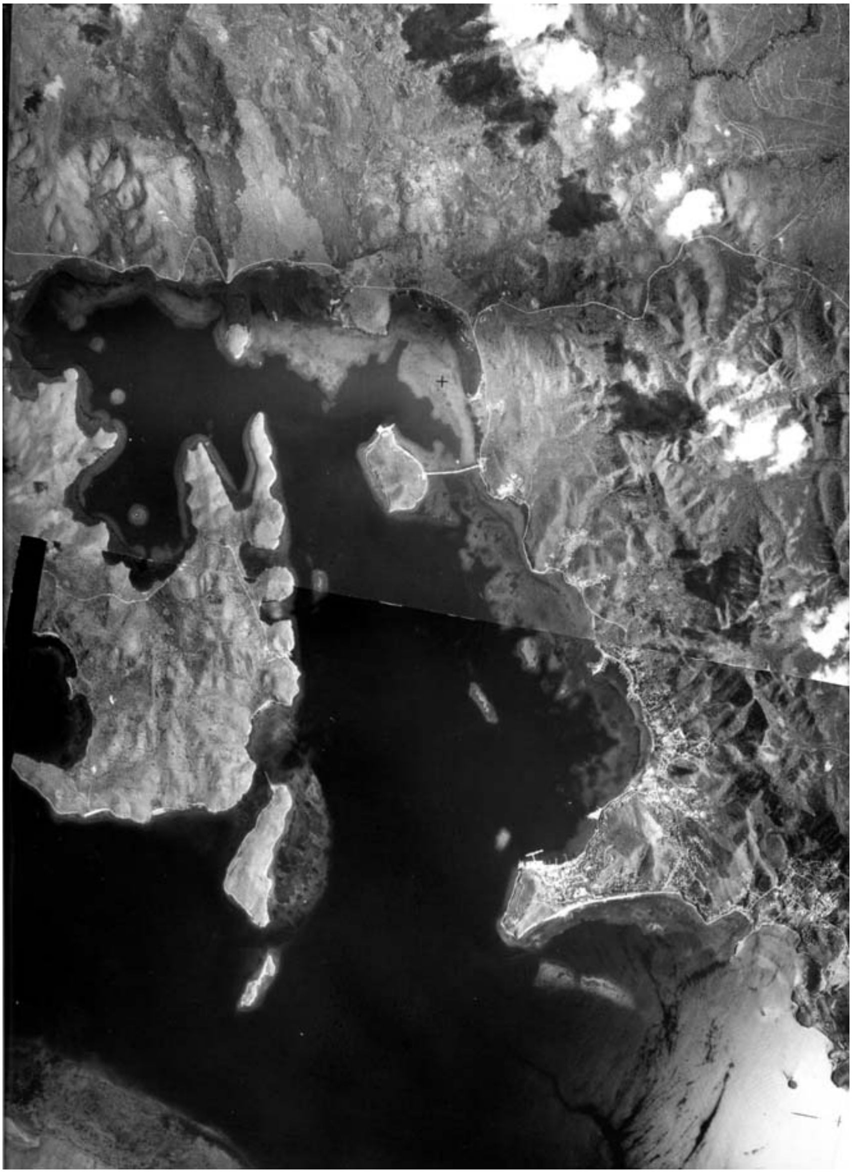
CONTENTS

Cover photo: highly magnified chain of *Pyrodinium* cells



Port Moresby Harbour, circa 1965. The water appears black in most of the photo. Port Moresby town is lower right. The pearl farm was in Fairfax Harbour, the left uppermost part of the harbor.

In the Beginning

The strange death of three young children in a small coastal village in far away Papua New Guinea in March 1972 did not rate a mention in the territory's annual report that year to its Australian governors—let alone make a ripple in international ponds. Yet, it was an event of incredible proportions. It marked the end of a chain of knowledge that extended back more than 45,000 years; it heralded the beginning of an era of immense, baffling phenomena and disasters around the world; and it marked the rise of a deadly poison from the seabed that would spread from country to country.

It is a story that encompasses much of the globe, from the Pacific islands to Asia—Brunei Darussalam, Indonesia, Japan, Malaysia and the Philippines—to the Middle East—Persian Gulf and Red Sea, and the Egypt of the Pharaohs—to the Pacific and Atlantic coasts of the Americas, and to Australia and Antarctica.

It is a detective story too, about who or what killed the three children, taking us in helicopters, light planes, speedboats and a naval patrol vessel, and on underwater explorations.

It is a romance spanning a period from the tail end of the Paleolithic era, pausing for a less ancient exodus, that of the Jews from Egypt, and for Cleopatra's—incredibly expensive as we will see—dinner with Marc Antony, and leap-frogging through events over the following two millennia via connections with Spanish kings, Napoleon Bonaparte, and the most famous pair to play the part of Cleopatra and Marc Antony in modern times: Elizabeth Taylor and Richard Burton.

Finally, it is the story of a young scientist sent unknowingly as a spy into Papua New Guinea shortly before its independence. How did he find himself enmeshed in the threads of this strange puzzle and what did he discover?

To put it all in proper perspective, we first need to look at some of the connecting threads.

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Humankind, we are more and more convinced, began to develop, had its nursery you might say, in the savannas of eastern Africa and over many millennia gradually extended northward, in times of suitable climates, crossing the Red Sea probably about 70,000 years ago in what we now call the Middle East. Wanderlust took some tribes further and further eastward, generally following the coasts, a route that took them around the edge of India, down the western side of the Mekong peninsula through the now Myanmar, Thailand, and Malaysia, and then via land bridges into the Indonesian islands and, later still, back up the eastern Mekong peninsula via Vietnam into China.

On a map it looks like a migration route or the movements of some vast army. But it was simply a gentle, perhaps inquisitive, movement of people looking for somewhere better to live than where they happened to be. They learned as they went, soaking up experiences and drawing lessons that were passed on to siblings, peers, and children.

By the last ice age—when much of the globe's water was in the polar ice caps and sea level was as a result very low—some of these "Asians," as they had become, moved on to the Sunda Shelf, a land mass that included the present islands in the east of Indonesia. Some island hopping must have then confronted travellers for the first time since the Red Sea crossing.

But island hop they did. Marking the beginning of Pacific islander life, they crossed in vessels to the Sahul Shelf, that is, the present New Guinea and Australia. This brings us forward to some 50,000 years ago. The ice age was continuing and reached a peak perhaps 30,000 years later. Then temperatures and sea level began to rise ever so gradually; it wasn't until around 7,000 to 6,000 years ago that New Guinea again became a separate island.

The important part of this brief history for our story is that once these “Asians” reached New Guinea 50,000 or so years ago, they stayed and their civilisation survived all those thousands of years. They invented their own agriculture and some tribes were so isolated in the highlands, they did not see humans from other civilisations until they came face to face with an Australian expedition in 1933, led by one James L. Taylor, Assistant District Officer of the Mandated Territory Administration and Mick Leahy, who, with his two brothers was prospecting for gold. The Australians and nearly 100 coastal New Guinean bearers crossed the highest ridges of the southern highlands and beheld not the empty mountains that successive colonists had presumed but, as the prospectors said, “a big parkland” with a “huge population” and “huge gardens”.

The residents, there were some one million of them, thought that they were the only living people on the planet and that the strangers were lightning from the sky or their ancestors returned. The New Guinean bearers, who could not understand the language of the highland residents, wore backpacks and these were thought to contain the bearers’ wives, while their red laplaps, or skirts, were thought to hide exceedingly large penises, so wives were not allowed to look at them.

It was a “lost” civilisation that had lasted some 45,000 years coming head-to-head with one that had been developing for only around three thousand years. The New Guinea civilisation was controlling its population by infanticide—killing newborns beyond the number that a tribe could look after and feed—concoctions from plants for contraception and abortion, natural contraception through continued breast feeding that could last several years, and sexual abstinence. Occasional warfare among tribes certainly helped keep numbers down too.

Horrifying as infanticide might seem in western society, it was a recipe for survival shared by the closely related Australian aborigines and by many Pacific islanders. The paradisiacal descriptions of Tahiti by early explorers and whaling ships in the 1800s were not only related to the availability of so many attractive women but also to their easy going society and garden-like agriculture—but it was maintained that way by pruning not only the food trees but also the population: infanticide was also their way to avoid overpopulating Tahiti.

During the last millennium, the coastal populations of New Guinea became exposed to visiting sailing ships from Asia and Europe. The western half of the island was claimed by the Netherlands and became part of the Dutch East Indies in 1828. The year 1884 saw the British claim the southern part of the eastern side of the island and Germany take control of the northeastern part. The western half remained Dutch, apart from Japanese occupation in the Second World War, until Indonesia claimed and took it in 1969, while the eastern half was taken from the Germans by the British after the First World War.

Japan controlled parts of the northern side during the Second World War, after which Australia, as a member of the British Commonwealth, governed the eastern half until self-government at the end of 1973. By end 1974, the eastern half of the island had become an independent country, Papua New Guinea.

All this fighting and political manoeuvrings over recent centuries concerned the island's central and provincial governments. In the thousands of villages dotted across the main and outer islands, the natives were happily isolated by and large from changing alliances and government intrigues. They were isolated from each other to a large extent, judging by the fact over 800 languages have been discovered among them; languages that were no doubt spoken at the turn of the 20^{th} century (1900), when there were not much more than half a million people known to be living in Papua New Guinea. And there was a vast population in the interior of the island, completely unaware of a world beyond their own and vice versa. All these populations, tribes, retained by word of mouth and in dance and carvings their culture and traditions and the knowledge passed down through generations, as they had over the previous 45,000 years.

They were intimately familiar with all the animals and plants around them: what could be eaten and grown in what season and what was to be avoided. Jared Diamond in his book *Collapse: How some societies choose to fail or survive* tells the story about Australian engineers in the New Guinea highlands who saw agricultural fields on slopes with drainage canals running straight down. They showed the farmers how to correct that primitive mistake by contour drainage as done elsewhere. The result was that when heavy tropical downpours came, the fields filled with water behind the contours and everything, crops and soil, was soon washed away. The New Guineans really knew what they were doing and why.

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The scene now moves to ancient Egypt, following the biblical story of Moses. Moses, according to biblical texts, wanted to take the much abused Israelite slaves out of Egypt, away from their servitude under the Egyptians to a place where they could practice their own religion. This demand was obviously unpalatable to the Egyptians. The pharaoh of the day denied the request and the country, in the biblical account, was in consequence subjected to a series of 10 plagues, one each time the hapless pharaoh denied Moses' repeated request.

Whether these plagues occurred at all, how many there were and to what extent, and when, and how many Israelite families there were and where they went are all matters of conjecture, myth or hard evidence, depending on your faith.

We are only concerned with the first plague, in which the Israelites' god turned the waters of the Nile and elsewhere into blood so that all the fish died and the water could not be drunk. There are many interpretations of this plague, among which a natural phenomenon offers the simplest explanation of the water turning red. When conditions are suitable, microscopic algae that are normally present in water in small numbers, begin to multiply at a great rate, or bloom, to the extent that they could turn the water red after only a few days.

What could those suitable conditions be? To visualize that we have to see the Nile, the longest river in the world, as it was, not as it is now, controlled in height and flow in Egypt by the Aswan Dam. Like large rivers in other parts of the world, the lower reaches of the Nile in Egypt were historically a huge flood plain. The river overran its banks seasonally, beginning in southern Egypt in mid-July and peaking in mid-August. Flood waters would cover the plain moving north and reach the Mediterranean Sea four to six weeks later. The flooding river water was laden with rich silt that fertilized the lower plain and became the basis of irrigated agriculture.

The fertilizing effect of silty water works not only on plants on land, but also on plants in the water. The aquatic plants in the Nile are mainly microscopic algae. These tiny single-celled plants are unlikely to proliferate when a river is fast flowing because they are carried out to sea and dissipated, as are the fertilizing agents, the nutrients. The Nile's flood plain had many meandering channels, most of which would be cut off as the flooding subsided and eventually dry out until the next flood. Calm waters in hot still conditions with abundant fertilizer around makes the perfect recipe for a bloom of algae—a red tide.

Among these tiny freshwater algae are species that kill fish by excreting poisons, others that actually feed on fish, and still others that simply use up all the oxygen and suffocate virtually all the organisms in the water. There are harmless ones too and the Egyptians were probably used to seeing patches of water in the channels discoloured by algae as the floods receded.

The Nile "plague" was probably the record of a bloom of poisonous algae one hot summer along the major channels and, if the waters slowed enough, possibly in the main branch as well. Such blooms would kill all the fish and would also poison water from the river that the people took in containers for drinking. Such red tides, as the phenomena are called, can last for days, months, or even more than a year. You can imagine the effect that a long period of undrinkable Nile water—with probably millions of rotting fish along the banks making the air along the river almost unbreathably pungent—would have on Egyptian daily life, which was cantered on the Nile.

The scribes of the Pharaohs loved to jot down events of the day and a great deal is known about ancient Egyptian life from as early as 5,000 years ago because much of it was written in ink on papyrus in a cursive script or in hieroglyphics on stone, a medium that lasts a lot longer than the average pocket book. It took centuries to work out how to interpret these scripts. Luckily, archaeologists found an Egyptian decree written on stone, the Rosetta Stone, executed in three languages, which finally gave scholars the clues they needed to “break the code.”

Yet, for all their penmanship and chiselling and scratching, the ancient Egyptians left no record of this or other plague, no mention of an event that should have confounded them and given rise to great speculation as to its meaning—a front page item in Egyptian written history. The absence of any record has allowed the imagination of many scholars to come into play and assign “authoritative” dates for the plagues ranging between 1600 and 1300 BC.

So perhaps either red tides in the Nile were not that uncommon after all or there were none.

The connections with our story do not end there. The bible relates that Moses led the Israelites to the Red Sea, whose waters were parted by their god for them to cross, after which he closed it on the pursuing Egyptians, destroying their entire army. Again, debate rages about the veracity of the story and where the crossing might have been if at all. The modern theory has it that these early refugees made their crossing at the Gulf of Aqaba, the northeastern horn of the Red Sea.

It was well known from ancient times that the waters of the Red Sea sometimes turned red. Of course, there are several other theories as to why it was so named, but the real cause of the red colour is simply occasional blooms of rusty red algae, also known as sea sawdust. These are harmless red tides found throughout tropical seas, the Red Sea being in the present era the northernmost tropical sea.

However, lurking within its waters and those of the nearby Persian Gulf, was another tropical red tide organism, one that was indeed a killer.

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Now we have to leap back in time again, 100,000 years ago, a good 30,000 years before our meandering ancestors had reached the Red Sea en route to their Asian odyssey. Climates were warmer than the present and this was probably the reason early humans were developing itchy feet.

The “tropics” extended over a lot more of the globe at that time. The mysterious killer from the Red Sea was a denizen of much of the world’s coastal waters, although, of course, there as yet were no humans around to be killed in most of them! In the western side of the Pacific Ocean, where much of our story takes place, our potential killer lived as far south as where Sydney, Australia, now stands. This much we know from the fossil record.

Over millennia, climates cooled, sea level fell as water turned to ice at the poles, and the cryptic killer-to-be retreated closer to the equator as the last ice age began—during which humans reached New Guinea and Australia—and afterwards expanded its range again. However, as far as was known in the 1970s, that range did not include the tropical western Pacific.

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Fast forward next to 47 BC in the time of Julius Caesar, most famous of the Roman leaders. At the time, the Egyptian Empire was waning fast, having been lost to the Assyrians and the Persians and finally to the Greeks over the five previous centuries. In fact, the pharaoh at the time was from a Greek family and destined to be the last of the line, the last pharaoh; she was Cleopatra VII.

Egypt and Rome were in conflict and Cleopatra was in exile. Caesar went to Alexandria intent on annexing Egypt into the Roman Empire but wily Cleopatra won him over by—as legend has it—being smuggled into his palace wrapped in a carpet, which was unfolded before him. Her charm evidently worked! She bore him a son and was allowed to rule Egypt again as a pharaoh.

Caesar was subject of a palace coup and assassinated three years later, in 44 BC, causing the end of the Republic of Rome and beginning of the Roman Empire. For Cleopatra, it meant looking elsewhere for a protector. This she found in Marc Antony, who had taken Caesar's side in the civil war that followed Caesar's death. Marc Antony defeated the armies of the opposition senators and took up with Cleopatra, intending to make wealthy Egypt the seat of Roman power. Alas, he lost the next round of civil war and committed suicide, leading to the legendary suicide of Cleopatra in sympathy, through the bite of a deadly snake. Egypt then became a province of the Roman Empire.

It is the relationship between Cleopatra and Antony that is important to our story. They shared a passion for lavish banquets, one in particular that has been handed down courtesy of an account in the world's first encyclopedia, that of Gaius Plinius Secundus, or Pliny the Elder, written between 77 and 79 AD.

Pliny's record of one of history's most famous dinners begins with some interesting information about pearls: "There have been two pearls that were the largest in the whole of history; both were owned by Cleopatra, the last of the Queens of Egypt—they had come down to her through the hands of the Kings of the East."

Well, how big is big? The largest surviving true pearl (Cleopatra's pearls did not survive long, as we will see) is one found off Burma (Myanmar) only a few years ago. It is not very pretty apart from its luster, resembling a brutally pummeled Lilliputian loaf of bread 3 centimeters high, 5 in width and 6 in length. Weighing 169 grams, it is nearly twice the weight of the previous but more elegant record holder, the Hope Pearl, which dates from around 1800; the Hope Pearl is 5.7 centimeters long, and resembles a battered cylinder. You can see the Hope Pearl in the British Museum of Natural History but the Burma pearl has temporarily vanished from sight, having been donated to Burma's military government, "thus avoiding the unpleasantness associated with an involuntary donation" said the company that found the pearl.

Pliny is the source of the legendary story of how Cleopatra and Marc Antony competed with each other in the lavishness of the dinners they prepared for themselves, a game that Cleopatra easily won. The evening of her turn to cook, so to say, she set out a sumptuous but otherwise unremarkable meal, which was ridiculed by Marc Antony—until she produced her coup de grâce, one of her fabulous pearl earrings, which she promptly dissolved in a glass of vinegar and drank! Actually, she would have had it crushed first or it would have taken hours or days to dissolve. Egyptian vinegar was strong stuff but the dissolved pearl would have neutralized its acidity enough to be drunk. Pearls are made of calcium carbonate, and calcium salts, of which the carbonate is one, are used to relieve indigestion. They do this by neutralizing the stomach's excess acid secretions. Thus, Cleopatra's pearl may have been the world's first and most costly antacid pill!

Cleopatra—according to the story that Pliny relates—valued that pearl at 600,000 sestertii. To understand why Marc Antony was roundly beaten by this unlikely meal, we need to know the value of a sestertius. Pliny answers this indirectly in a tirade against Roman women displaying outlandishly valuable jewellery. Lollia Paulina, one time wife of the infamous Caligula, wore at a wedding feast alternate rows of pearls and emeralds all over her head, ears, neck, hands and fingers, worth 400,000 sestertii… "and offered to prove it immediately by her Books of Accounts." The wedding was with people of ordinary rank, not even (Pliny is livid) a state occasion.

Pliny compares the value of this one "reclining woman" with the spoils brought back from conquered provinces by Roman generals and concludes "would...that they had been pulled out of their chariots than to have conquered only for this."

The Encyclopedia Romana is more definite, concluding that the value of each of Cleopatra's pearls was equivalent to about 1,764 pounds weight (800 kilograms) of gold, which at the present US$1,500 an ounce means more than US$42 million. Some pearls!

A friend of the banqueting couple, acting as judge of this extravagant wager, stopped Cleopatra from turning the second pearl into a cocktail. But we know that the second pearl did not survive either because when Cleopatra was later taken prisoner, it was cut in two and the halves hung on the ears of the statue of Venus in the Roman Pantheon.

Pearls were certainly the fashion in Rome at that time, Pliny scathingly noting that women would wear two or three very expensive matching pearls on each ear to hear them rattle, and they were not put only on the upper part of their footwear but all over it: "it is not enough to carry pearls about with them, but they must also tread upon them, and even walk among pearls."

Julius Caesar invaded Britain in 54 BC. He did not stay to conquer the island and it said that he was more interested in the freshwater pearls that were to be found in British rivers. These were much inferior to marine pearls but good enough for Caesar to use later in a breastplate made completely of British pearls that he placed as a dedication in the Temple of Venus Genetrix.

Indeed, English pearls have their moments. One of the most famous freshwater pearls is the British Abernethy pearl, found in 1967 in a horse mussel in the Tay River; it is almost perfectly spherical and was said to have been sold for 60,000 pounds (about US$96,000 at the time of writing). And for the past century or so there have been in London pearly kings and pearly queens, individuals who cover their clothing in pearl shell buttons to attract attention as they collect money for charities.

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Pearls, as we will see, are central to solving the mystery of the deaths of those three children on the other side of the world almost exactly 2,000 years after Cleopatra's suicide in 30 BC. But why and when did pearls enter people's consciousness?

The origin of Roman love of pearls is hard to pinpoint. The oldest known pearls may be two found in an excavation site in Kierikki in 2006, in the present Finland, dated at between 6000 and 5000 BC. Around the Persian Gulf, the Red Sea and Oman and Iran to the north—mother of pearl was used for inlay and beads and plaques going back to 6500 BC and pearls are known from graves dated 3500 to 4000 BC. The Egyptians used pearl shell extensively in dress and in their tombs as ornaments as early as the fourth millennium BC, possibly around 3500 BC. But they preferred gold and other gems to pearls, which were rarely used.

In Asia, the Indian Vedas, the world's oldest sacred "writings"—they were handed down orally in the early centuries—mention an amulet of pearls, in the Rigveda of around 1500 BC. The Indian Ramayana poem, written in the sixth century BC, describes an elaborate pearl necklace. Pearls are mentioned in the Chinese Rh'ya, a dictionary of terms begun in 11 BC, but added to until perhaps 300 AD. They were recorded as a tribute or tax in China around 200 BC.

When the Persians first conquered and founded a dynasty in Egypt in 525 BC, the Persian Gulf was already well known for its pearl beds The Persians probably introduced the ornamental use of pearls to the Egyptians around that time. Edward Fitzgerald, in his translation (in the nineteenth century) of the famous 11th century poem *The Rubáiyát of Omar Khayyám*, was mindful of Persian pearls. A short Foreword says:

> These pearls of wisdom in Persian Gulf were bred,
> Each softly lucent as a rounded moon;
> The diver Omar plucked them from their bed,
> Fitzgerald hung them on an English thread.

By the time the Greek Ptolemy dynasty—the 32nd Egyptian dynasty and destined to be its last—began to control Egypt in 305 BC, pearls had begun to appear in large numbers, particularly in Alexandria. Cleopatra VII, a member of the Ptolemy family, became the pinnacle of this fashion. Sadly, Alexandria later declined to the extent that when Napoleon landed there in 1798, it was not much more than a fishing village.

Pearls have rarely gone out of fashion or demand since Roman times. The classic 1908 *Book of the Pearl* by George Kunz and Charles Stevenson records that the popularity of pearls moved east with the transfer of the Roman Empire's capital by Constantine the Great to Byzantium (which became Constantinople and later Istanbul) in 330 AD. Enormous collections of pearls were made because Byzantium controlled trade between Asia and Europe by virtue of its location at the crossroads.

Pearls remained the favourite ornaments in the East over the centuries. Meanwhile, to the west, Rome itself fell to the Goths in the fifth century AD and its treasures, including pearls, were "scattered among the great territorial lords of western and northern Europe." These scattered treasures were further dissipated by the Franks when they conquered the Goths in the early sixth century.

During this time, the rulers of India and Persia, who controlled between them the only known marine pearl fisheries, began to collect great quantities of pearls, which were, according to all accounts, the most precious of their jewels. Marco Polo described an Indian potentate wearing not only a huge pearl necklace but also pearl anklets and rings on his toes, in a revival of ancient Roman fashion.

The Franks were equally fond of gems and by the seventh century, pearls, along with other gems, were finding their way as ornaments in church vestments, shrines and reliquaries. Charlemagne—who ruled the Franks from 768 AD, became Emperor of the Romans in 800 and reigned until dying in 814—took this to a higher level, encouraging the use of gems in the binding of hand-written manuscripts. The texts that were produced, mainly sacred works, were sometimes a scribe's lifetime's work; the binding had to be correspondingly magnificent and pearls were a common ornament. One of the most remarkable of these is said to be the Ashburnham manuscript of the Four Gospels, the cover of which was made near the end of the ninth century and contains 98 freshwater pearls.

Charlemagne's empire included most of western and central Europe and began an early cultural renaissance. However, his death resulted in Europe splitting into many separate nations, scattering once again the collections of pearls and other gems, following the conquests of the Vikings during the ninth century and their Norman descendants during the following two centuries.

The next two centuries in Europe were dominated by the crusades. The twelfth and thirteenth centuries saw the crusaders bringing back to England vast amounts of jewels, including pearls. Consequently, there was an upsurge in the display of pearls among the fashionable sets in the following two centuries. Henry VIII "released" many pearls from Catholic churches, which further increased their presence among important women in England, especially on his wives, as their portraits show.

Pearls remained the most prominent ornamentation in Europe from the fifteenth century, a phenomenon that finally caused reverberations and backlashes around the continent. "Sumptuary" laws were put in place in many European countries during the fourteenth to sixteenth century in efforts to restrict the wearing of pearls. This was not an entirely new fad. Tacitus, a Roman senator in the late first and early second century AD, abhorred the use of pearls to symbolize wealth and prestige. He advocated that only women of a designated position and age should wear them and only on set days.

Kunz and Stevenson wrote that “an entire volume might be devoted to the efforts to curb their excessive use.” In Germany, for instance, Bishop Tudertinus excommunicated any woman seen wearing pearls. Apparently, many women flouted this measure, with the defence that it was only binding to those who accepted it!

Even Venice, a major centre of trade during this period, faced severe restrictions on wearing pearls, and the restrictions became more so over the years. By 1599, only women during their first 15 years of marriage were allowed to don pearls and ten years later, seeing that this restriction was not working well, the wearing period was reduced to ten years and banned for any other purpose, even being worn at home; neither could pearls be any more imported into Venice.

There was some basis in the new testament of the bible for Bishop Tudertinus's stance— *Women should adorn themselves in modest apparel, with shamefacedness and sobriety; not with braided hair, or gold, or pearls, or costly array.* The description of heaven was something else, however; each of the 12 gates of heaven was made of a single pearl and heaven itself was likened to a pearl of great price.

The Islamic Quran, incidentally, also places a high value on pearls. Those admitted to Paradise *shall be adorned therein with bracelets of gold and pearls*. Their women companions have *beautiful, big, and lustrous eyes, like unto pearls* and the *male servants in Paradise are boys who are like unto pearls*. And Hindu mythology refers to nine sacred pearls.

Meanwhile, the sixteenth century brought to light one of the most famous pearls of all time. It was a silvery white, pear-shaped piece and the largest pearl found until that time, and still the 15th largest pearl ever found. The saga began with Christopher Columbus, whose explorations and discovery for Europe of the American continent fired the imagination of a certain Vasco Núñez de Balboa.

Only 17 when Columbus reached America in 1492, Balboa became an explorer and conquistador for the Spanish throne. In 1513, struggling through the Panamanian jungle from the east to its west side, he became the first European to see the Pacific Ocean. The year was 1513. Before him lay the Gulf of Panama and beneath it, as he soon learned, beds of pearl shell to rival those of the famous pearling grounds in the Persian Gulf.

Before long Balboa was in control of a thriving pearling industry in what is now known as the Archipielago de las Perlas, systematically cleaning out the pearl beds until the shores of the gulf and its islands were covered in dead shells. Presented with the huge white pearl, he gave it to the Spanish administrator of the Panama colony. Unfortunately, such acts made him too popular and the Governor had him arrested for treason and executed in 1518.

The pearl, however, was by then already on its way to Spain, presented to then Spanish king Charles V. A few decades on, a Spanish prince noticed the pearl in the royal collection and gave it to Mary Tudor as an engagement present. She became Queen Mary I of England in 1553. They were married in 1554, having met each other only two days before—one wonders if the pearl had some influence! And he became King Philip II of Spain in 1556.

Mary died after a bloody five-year reign during which she prosecuted and had executed or burned at the stake, all the followers she could find of the new Church of England, begun by her father King Henry VIII, that broke away from the Catholic Church.

The pearl then went back to Spain but adorned many a European royal personage over the succeeding centuries, including Spanish kings Philip III (1598-1621) and his wife, Margaret of Austria, and Philip IV (1621-1665) and his wife, Isabel of France. There was no mistaking whether it was the same pearl; it appeared in anonymous paintings of Queen Mary I and in portraits of Spanish royalty by the now famous 17th century artist Diego Velasquez.

In 1808, Napoleon Bonaparte captured Spain, along with the royal jewels, and declared his elder brother Joseph the new king. It was a short-lived reign. When the fortunes of his brother waned and he was finally conquered in 1815, Joseph fled, taking the pearl with him, to France. Later, he emigrated to the United States. Toward the end of his days his nostalgia for Europe overcame him; Joseph died in Florence, Italy, in 1844. He willed the pearl to his nephew, Charles Louis Napoleon Bonaparte. By then the pearl had become known as La Peregrina - the Wanderer.

Charles Louis Napoleon Bonaparte, one of France's great historic figures, was elected President of the country and later, in 1852, declared himself Napoleon III. From La Peregrina's viewpoint, suffice it to say that he made the mistake of initiating the Franco-Prussian war of 1870, was captured, released, and spent his last three years in exile in London. During those last years, he was in financial trouble and sold the pearl to Lord James Hamilton, the 2nd Marquis of Abercorn.

Lord Hamilton presented the pearl to his wife, Lady Hamilton who, in turn, gave it to her son, the 2nd Duke of Abercorn. In 1913, he restored the pearl and its setting, as a result of which it lost the 5 carats that slightly lowered its ranking among large pearls from 15th to 16th position (at 51 carats), and from 4th to 5th in rank of pear-shaped drop pearls in the world. The pearl stayed in English hands until the Hamiltons decided to sell the pearl in 1969 at auction by Sotheby's.

In an uncanny 3,000 year rewind, Richard Burton, who appeared as Marc Antony in the movie Cleopatra in 1963, bought the pearl at the Sotheby's auction for $37,000, had it reset in diamonds and smaller pearls and gave it to Cleopatra herself—the actress Elizabeth Taylor. Her writings tell of her love of pearls, especially La Peregrina just as, history shows, the original Cleopatra loved pearls.

After Taylor's death in 2011, the pearl, along with her other jewellery, was auctioned at Christies for a world record price for a pearl, nearly $12 million. It was nothing less than a fitting tribute for a 500 year old pearl that has graced royal families through its life. Nor has the pearl stoped its wanderings. The new owners are from South Korea, where it will put on display.

From the seventeenth to the end of the nineteenth century, pearls were avidly collected by those who could afford them, especially royal families in Europe. By the time photographic portraits were becoming popular in the mid 1800s, ornamental pearls were the most popular decoration, being used not only as jewelry in necklaces and brooches but also on all items of clothing, headwear and footwear.

About this time, fashion also discovered black pearls. They are said to have been popularized by the last Empress of France, Empress Eugénie de Montijo, wife of Napoleon III, who was thus the second most significant person in pearl fashion history, after Cleopatra, last pharaoh of Egypt.

What is surprising and generally not realized is that black pearls come from the same pearl oyster species that produced Cleopatra's famous and undoubtedly slivery white pearls.

Even the largest available pearl, the Hope, is from this oyster as is clear from the dark outer edge. The only other pearl oyster that could have made such a large pearl is the goldlip, whose pearls are not formed in dark colours.

Black is a misnomer though. "Black" pearls are silvery grey to dark grey to dark green and violet, very rarely close to pure black. These pearls, shunned for nearly two and a half millennia, suddenly became very valuable indeed through the later nineteenth and twentieth century—until they came to be mass produced in the last few decades as we will see.

Fake pearls entered the market during the seventeenth century. The first ones could not have been very convincing, thin hollow glass spheres filled with a pearl essence made from fish scales. Since then, numerous chemicals and processes have been used to trick the eye, sometimes very successfully.

Black “pearls” made of haematite are a popular deception by vendors in the Philippines (and elsewhere) who offer them, swear by them, as black pearls. They also sell wonderfully translucent, opalescent, baroque white pearls, so wonderfully bright and translucent you can see light through them—which, of course, is impossible in a real pearl. Nevertheless, buyers are happy with their bargains, and those who admire such jewelry are likewise ignorant of the nature of pearls. In the twenty first century, this audience probably includes more than 90% of us. A good market.

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The next thread in the story concerns growing, or farming, pearls. Natural pearls are uncommon in pearl oysters, and spherical pearls—as fashion seems always to have decreed the most valuable pearls should be—are quite rare. The desire to sidestep nature and stimulate the oysters to produce more pearls led to pearl culture as long ago as the thirteenth century in China. A certain Ye-jin-yang discovered that he could produce pearls in freshwater mussels in the lake beside the city of Tehtsing (now Deging). The process was remarkably similar to that practiced everywhere today—the animal’s shells were gently opened and such irritants as pellets of prepared mud or pieces of bone, brass or wood inserted. A specialty was to insert tiny lead or tin images of the Buddha. The mussels were then kept in ponds fertilized occasionally with night soil (!). After months to years, the pearls were removed and the mussel flesh eaten (!!). Pearls are still cultured near Deging today in much the same way and millions were being sold annually by the early twentieth century.

The famous Swedish naturalist Linnaeus (Carl von Linne)—who, among other things, gave us the way we classify living animals and plants—first made perfectly round pearls, in the mid 1700s. Probably wishing to improve on the Chinese method, which did not usually produce round pearls, he inserted an irritant on a silver wire in freshwater mussels; the wire prevented the irritant from becoming attached to the inner shell like a blister pearl. In the late 19th century, both in Tahiti and in Western Australia, some pearls were produced by inserting irritants through holes bored in the living oyster's shell; the holes were then covered.

The technology for producing pearls reliably from pearl oysters dates only from the early twentieth century and is usually ascribed to the Japanese technician Mikimoto, who began producing round pearls in the early years of the century. The term *Mikimoto pearl* was used for the next half century or more to describe all cultured pearls. Indeed, the Japanese had complete control of the cultured pearl industry during that time because only Japanese technicians knew how to implant the nucleus that generates the round pearl in the oyster.

However, this brief account of modern pearl culture hides an intriguing series of events. Enter British biologist William Saville-Kent, who among other things was a Fellow or President of several prominent British and Australian biological societies; Commissioner for Fisheries at different times for the governments of Queensland, Tasmania and Western Australia, respectively; and author of some major publications including a tome on the "Great Australian Barrier Reef". Saville-Kent had strong interest in pearl culture.

The Encyclopaedia of Australian Science says that he "probably spent a good deal of the time between 1896 and 1907 in tropical Australia and adjacent areas engaged in pearl oyster culture." When goldlip pearl oysters were introduced from Australia into the Cook Islands in 1904, he went there to oversee pearl culturing experiments. Lever Bros. imported a stock of goldlip pearl oysters to the islands in that year and apparently they reproduced successfully; however, most of the young were eaten by fish and octopi, the remainder and adult stock being lost in a cyclone several years later. Saville-Kent went to England in 1905 and formed a pearl culture company that set up shop at Somerset in Queensland just below Cape York.

The Australian Dictionary of Biography notes that "He was probably the first to succeed in producing both blister and spherical pearls of commercial quality—a necklace believed to have been made with his pearls has recently attracted specialist attention." Saville-Kent died in 1908, apparently taking his technique with him.

Meanwhile, in 1901, the Japanese government sent Tokichi Nishikawa, a biologist, and Tatsuhei Mise, a carpenter, to investigate the pearling situation in Torres Strait, a major pearl diving area between tropical Australia and New Guinea. They spent about six months in the area where Saville-Kent was doing his experiments and, back in Japan, both applied in 1907 for patents on the technique of pearl production by inserting an irritant, in this case a sphere made of some inert material, together with a sliver of oyster mantle tissue, the process still used universally today. Mise's was the first, claiming discovery in 1904.

According to an essay on the subject by a modern-day pearl farmer, Denis George, Nishikawa's application backdated his discovery date to 1899, a matter of months after his graduation from university, which was not believed by his peers, so Mise's application prevailed; he and Nishikawa finally agreed on a jointly named pearl culture technique, which they patented in 1908. Nishikawa later married a daughter of Mikimoto, who, apparently as a result of this union, was able to make use of the new technique. The evidence points to Saville-Kent as the source of the technique.

This is a far cry from the usual glowing descriptions of the discovery, in which Mise and Nishikawa were said to be researchers who independently discovered the technique and in 1907 separately applied for a patent. When they discovered that they had both applied for the same discovery, they signed the Mise-Nishikawa agreement and Mikimoto, also applying for a patent the next year, bought the rights from them. There are, too, even more glowing accounts in which Mikimoto single-handedly made the first cultured pearl.

Denis George, who researched and published of some of this information on the role of Saville-Kent and his Japanese visitors, was an irascible Greek-naturalized-Australian pearl farmer at Samarai off the eastern tip of the Papua New Guinea mainland when I met him. He was previously a pearl diver in Torres Strait and said of himself that

> "For 10 years I researched and experimented with pearls by trial and error until this culminated in technical success at my private pearl experimental station at Packe Island near Thursday Island. During this time, I had discovered pearl techniques while being ignorant of the Japanese method."

But then again, Denis had married a lovely Japanese woman, Yuli, who had attended a Japanese college for pearl culture and was an expert in seeding oysters with the sphere that becomes the nucleus of the cultured round pearl.

Saville-Kent's idea was to introduce the spherical irritant into the oyster's tissues in a way that the oyster could not dislodge it, by making an incision in the tissue, generally the gonad, and pushing the irritant in among the tissue. The irritant, the nucleus, was a sphere of shell carved from a common freshwater mussel.

However, the tissue that makes the substance of the pearl, or nacre, is not in the gonad but in the soft tissue around the outside of the oyster's body, known as the mantle. Thus, a tiny piece of mantle tissue from another oyster is placed alongside the nucleus inside the incision. Generally, the tissue survives and busily secretes nacre around the nucleus, and continues doing this for two to three years until the oyster is opened and the pearl excised. Often, another nucleus and piece of mantle can be inserted and the oyster put back in the sea and left to its own devices to manufacture another pearl.

Refinements have been made over the years. For instance, common practice is to weaken the pearl oyster before operating to insert the nucleus. The oysters are subjected to stress, such as raising and lowering them in the water or moving them to warmer or cooler or more or less salty waters. The desired result is that they spawn and empty their gonads. Stressing the oysters might seem counter intuitive but is done to lower the energy of the oyster enough to prevent it from rejecting the nucleus. It is a delicate balance; too much weakening can kill the oyster, and if the muscular wall of the gonad becomes too thin, the nucleus will fall out. If the oyster is too strong, the nucleus may be rejected by muscular contraction and pop out through the incision.

The Japanese government certainly realized the value of pearls. It issued in 1953 a "diamond policy" with regard to pearl farms overseas, specifying that pearl cultivating techniques would remain secret to all but the Japanese, production would be controlled and regulated to safeguard the home pearl production, and all pearl production would be exported to Japan. The secrecy aspect assured a monopoly in the technique for several decades and even today, nearly all pearl technicians are Japanese.

Just as there are fake pearls there is also fake pearl culture. Among Malayan cultures of Southeast Asia, it was long believed that pearls placed in a sealed box with some grains of rice would grow in size and additional tiny, or seed, pearls would form and grow. Variations on the method were to fill the box containing the pearls and rice grains with cotton, freshwater or seawater. No doubt the idea still has hopeful adherents and is used to embellish the lustre of fake pearls in the eyes of unsuspecting buyers.

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The connections between red tide and pearl oysters became very thin after that biblical deadly red tide in Egypt and the presence of harmless red tides and potential killer red tide organisms in the Red Sea and Persian Gulf. Those two water bodies were the sites of major pearling grounds and the main source of pearls over the following millennia as pearls grew in popularity and fame, for some of which we have Cleopatra VII to thank or blame.

Red tides were undoubtedly appearing and disappearing during all these years and centuries. Old Korean literature suggests red tides have been known in that country for some 2,000 years. On the Pacific coast of the Americas, the Florida red tide that today continues to cause massive fish kills and inconvenience to coastal residents was long known to Indian tribes and recorded as such by Spanish explorers in the sixteenth century.

The connections unexpectedly strengthened again in a major confrontation in Japan little more than a century ago. In 1892, red tide swept through the bay where Mikimoto's oysters were growing. Most of the crop was killed and, near bankrupt, he almost gave up in his effort to produce pearls. He started again but another red tide, 13 years later, when he was still short of his goal to produce spherical pearls, again wiped out most of his oysters, this time nearly a million of them.

These were not the first red tides to hit Japan. A 300-year old Japanese history book (Dai Nippon Shi) refers to red tides as early as 731 AD. A deadly red tide in 1234 AD killed many fish as well as humans who ate the affected fish. However, in the first half of the twentieth century there were only 1 or 2 reports per decade of red tides in Japan, including harmless and freshwater red tides. Mikimoto was just unlucky.

Strangely—but we shall dispel the mystery later—red tides and associated major fish kills (usually in offshore fish farms) in Japan increased dramatically in the 1970s to more than 200 reported events *annually*. It was a time when heavy industry in coastal areas was booming as was fish and shellfish farming.

The Japanese pearling industry—the largest pearl culture business in the world—was justifiably worried. Countless thousands of pearl oysters, each worth a considerable sum, were dangling from ropes in dangerous waters, like so much bait. Sure enough, in 1992, a huge red tide took the bait. Hundreds of thousands of pearl oysters died in an eerie repeat of Mikimoto's woes nearly a century earlier. However, other pathogens, of unknown origin, were apparently worse and brought Japanese pearl culture to the brink of collapse in 1996 and 1997, although it has since recovered, however temporary that recovery may be.

From There to Here

It would be unfair to take the reader through so much ancient and not-so-ancient history and not give some even-less-ancient history about the author. We must weave threads from his life into the developing story, which will show us how he came to be in a most inhospitable place at a most inauspicious time.

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Ever since I was old enough to fall into the ponds of Centennial Park in Sydney, Australia, I have had a strong interest in aquatic life, particularly mine. Falling into the ponds was an occupational hazard of the business of catching the tiny guppies that inhabited them. The fishing technique was a piece of bread in a bottle held by a length of string; sometimes the bread floated away and you had to go after it….

Not only fish, the leaky putty-lined aquarium I defended in my parents' small apartment contained whatever forms of life could be netted or dug out of the ponds of Centennial Park. There were tadpoles, a jungle of local water weeds, whirligig beetles, larval dragonflies, baby eels and later even baby lampreys. From the pet shop came newts, large white passive creatures that had pink external gills like small cauliflowers, large fleshy tails and tiny feet; they spent their time unmoving, staring apparently vacantly until, with a really fast snap, they would gulp down a worm that showed itself above the sandy bottom. The baby eels, called elvers, shared my family's fascination for the newts; the eels lurked in the sand and would pop up beneath the newts, bite off a leg or piece of tail and promptly disappear again. The newts seemed to tolerate this eccentricity on the part of the eels until, severely mutilated, they would rise to the surface and hang there for a week or more while the parts regenerated and then they would sink down in search of worms, to become eel dessert once more. Aquatic biology was engrossing.

Insect collecting was a second biological hobby. A neighbour about my age and I would make serious collecting trips as far away as the National Park, way past the end of the southern Sydney suburban railway line. We learned the seasons of different butterfly species, their habits, likes and dislikes among the bushes and flowers, times of day when they were active, when the invasions of the big wanderers and pierids (the white butterflies) would occur, how to catch the swordtails by throwing up overripe fruit into the ti-trees and catch them as they flew down from their regular circuits on the tree tops to investigate, how to find their caterpillars and rear them on certain leaves. I could tell close species apart from a great distance after a while by watching the length, height and direction of their flight.

Details of the catches were carefully written down in tiny print in good quality black ink with a fine-nibbed pen, giving details of where and when they were caught. The places, date and name could be written on a ¼ inch square piece of board attached to the same pin that held the specimen. Species names were typed onto small strips of paper and pinned under a row of specimens. Nearly all were held in place by special entomological pins—they made one feel quite professional and were only available from one scientific supply store in the city. Some insects were too small to be pinned and were glued to tiny rectangles of thin board that were in turn pinned with the lovely sounding entomological pins.

Even more professionally, I would occasionally take specimens to the Australian Museum for identification. I can't imagine why the staff humoured me, but time after time I would go in a side entrance to the working part of the museum and either retrieve an identified set or bring in more for identification. Perhaps they were expecting any day a new species to come their way.

There were certainly magnificent insects to be seen in the museum, which had an incredible collection on display from all over Australia and the Territory of Papua and New Guinea and you could see that the tropics held the largest and most flamboyant insects. It was my favourite part of the museum—well, after the mysterious Egyptian room where I always fancied that it was possible for one of the mummies to unwind and come alive. The superiority of tropical butterflies was confirmed in my own precious book of Butterflies of Australia and New Guinea by Barrett and Burns. There was even a full page black and white photo of a “Native of New Britain (in Papua New Guinea) with a birdwing butterfly as head-ornament” There it was, the largest butterfly in the world, sitting on his woolly hair, tied on with a piece of twine. Another full page photo was of “Rouna Falls, Papua. Haunt of Papilios, Nymphalids, Pierids, and ‘Blues’”, so alluring to my young mind. I already knew what those big words meant; I could almost see those butterflies soaring and darting through exotic jungles. I would get to Papua New Guinea one day, I promised myself, somewhat prophetically. Yet, as things were for a boy in a small rent-controlled flat in suburban Sydney, Papua New Guinea might as well have been on the moon, so remote was the prospect of going there.

Meanwhile, I began to wonder about the similarities and relationships of all my insects. They had stories to tell, about which I wanted to know more. I could sort them into families and species groups as a result of my museum identifications and the displays there. I began to draw them too, with the intention of someday producing an identification guide. There were no books of that nature on Australian insects at that time. I could have written a practical entomology book by the time I discovered girls.

The knowledge gained from such pursuits was of no immediate use. Waverley College, where I spent all my primary and secondary school years, had no truck with anything that sniffed of biology, especially girls. Chemistry, Physics, Mathematics, English, Latin, Religion—this was the stuff of men to be.

Nor was body surfing, which filled much of my recreation time on summer weekends, seen as a legitimate substitute for the dreadful physical education rites we had to perform in the college’s tennis courts several times a week. “Phys-ed” gave me an aversion to aerobics. Body surfing gave me an enduring love of the sea.

I became an expert body surfer in all conditions, and could effortlessly peel off an impending dumper and swim to the big ones "out the back" and catch them all the way onto the beach; I could do body rolls as I came down the front of a wave and turn left and right to avoid those who thought surfing was to stand up, get knocked down by a wave, and stand up again and again and again. Whatever my future held, the sea was going to be part of it.

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Escaping from Waverley College with a high-school matriculation, I obtained a scholarship at the University of New South Wales and found to my great joy that among the science subjects was Biology. So I enrolled, in 1961, in the Science faculty on a Biology-Zoology track, which involved doing a double major—in Zoology and Biochemistry.

Biology was wonderful; contact with the real world at last. The lectures on evolution and biology in general answered the riddles posed years earlier in my insect collections. I could suddenly see how they developed and why there were similarities that enabled me to sort them into each group. For me, evolution gave biology its third dimension, that of time.

Biochemistry had little appeal. It struck me as a science that was so incomplete and inexact; it was not ready to be taught. Even then, metabolic pathways were extraordinarily complicated systems that needed poster-sized diagrams to illustrate properly. The helical structure of the cell's hereditary material was already known and hailed as the final breakthrough in our understanding of body chemistry. But it was one type of chemical in what must be hundreds or thousands of long- and short-lived compounds surging through blood vessels and tissues at any one time.

We ingested metabolites and peed into bottles (girls used beakers or jam jars) to show certain reactions. We smashed the skulls of pink-eyed white rats on the bench tops to sample their blood. The experiments were gross in many ways and the accuracy of results poor. Equations were mainly qualitative at best. Dixon and Webb's book on Enzymes and the second edition of White, Handler et al's Principles of Biochemistry were bibles whose contents by now have probably been replaced almost entirely.

Body surfing meanwhile, for which no course or degree was offered, remained a strong attraction. A group of like-minded friends, myself included, formed in that first halcyon university year the BSC, the body-surfing club, in a play on the acronym for the Bachelor of Science (B. Sc.) degree we expected to attain sometime in the distant future. BSC members wore a dog tag, which was probably the most practical aspect of the club. If we were drowned or partly eaten by a shark, we could be identified. At the time, we never considered those possibilities; the tag and chain formed the bond between daring surfers.

And surf we did, not only in summer but also right through winter, because the best surfs were in winter, when the big boomers began to break some 200 meters out and rolled down in perfect curls right into the shore. There were dangerous rips that would have closed the beaches to swimmers were there lifeguards on duty. The water was sometimes very cold and I am amazed to recall our endurance, wearing nothing but brief costumes; and we knew there were sharks off those beaches, especially in winter when the water was coldest.

Zoology began in the second year of the science course and was a fascinating journey through the animal kingdom comparing how we animals all "worked". It became more intense the next year and my fascination with the subject intensified to match. I easily completed the course and together with a limping pass in Biochemistry II, earned my Bachelor of Science (B.Sc.) degree. Thus ended the first stage of my tertiary education, with a love of zoology and the sea.

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I wanted to continue zoological studies for an honours year and beyond, preferably in a subject that would take me into the sea, hopefully ending in the tropics. Papua New Guinea, as an

Australian colony, seemed now within reach someday and conjured up not only monstrous butterflies but also “wildness” and aquatic underworlds to be explored. However, there was no aquatic subject at the University of New South Wales, and with my other non-human biological interest being insects, I leaned toward an honour’s degree in Entomology.

Fate stepped in for me then. The only Entomology instructor was killed when he was photographing a car race; an entomological career was suddenly not an option. Instead I studied for my honours degree the metamorphosis—the change from juvenile to adult—of larval lampreys, eel like creatures that lived in the rivers of southern New South Wales. At least it was vaguely aquatic research.

The larvae, or ammocoetes, of the local lamprey had a strange pouch hanging off their otherwise tubular intestine; the pouch was gradually absorbed and disappeared after the lamprey metamorphosed, that is, changed into the adult form. What was this strange pouch? No one seemed to have looked at it seriously. Studying the internal workings of the ammocoetes required optometrists’ scalpels for dissection and very fine glass tubing for sampling blood and injecting dye into almost microscopically small blood vessels. The whole animals were only 10 centimetres long and the pouch, or diverticulum, only a few millimetres.

On occasion, specimens had to be anaesthetized, and slit open to observe the blood flow and inject veins and arteries with dyes to follow the pattern of blood circulation. Everything was done under dissecting microscopes; tissues were preserved, stained, and then embedded in wax, cut to a few microns width on a microtome, and observed on glass slides under a high-power microscope. My biochemistry background came in handy after all; I was able to find out the function of the pouch with the help of a few chemicals and a centrifuge.

It was my first real research and I threw myself into it. Apart from the laboratory work, the various tiny parts of the ammocoetes had to be drawn painstakingly in the scientific style; lettering was done with a plastic stencil that needed a lot a patience to use "professionally". If you made a mistake, it was literally back to the drawing board and a new sheet of paper. And there was photography—not just taking photos (using 35-millimetre-wide film) through a microscope and of the drawings, but also developing and printing in the Zoology Department's darkroom the photos in the various sizes that I needed for their proper display in my thesis report.

I was even enthusiastic about developing and printing the photographs because as a child my Saturday nights were often spent watching my father and his friend Mr Hosey printing their own photographs in a makeshift darkroom behind Mr. Hosey's store in Randwick. I got to understand the whole process, which was a real art form to carry out professionally. Besides, for a 7-year old boy, it was verging on the paranormal. Alas, almost overnight it died. Just as digital compact discs or CDs quickly wiped out a long generation of vinyl records, digital cameras, with their versatility and the ease with which pictures can be manipulated and transmitted, dealt a mortal blow to film at the end of the twentieth century.

Film still gives better resolution than digital equivalents but this superiority will probably be lost as digital cameras improve. Nevertheless, one can be sure that film will retain its niche market with snob and rarity value, so it is still handy to know about. I was lucky to be from a generation that knew not only how to develop and print photographs but also understood what was under the bonnet of pre-computerized motor vehicles and how to do simple math without a calculator. It was a more hands-on generation, and that applied to research as well.

My thesis research was very successful. The ammocoetes pouch was shown to be the precursor of the pancreas and a previously unknown evolutionary step between the very simple digestive system of *Amphioxus* (or lancelet, then known as the most "primitive" vertebrate, or backboned animal) and that of "higher" vertebrates. As aquatic vertebrates became more sophisticated in their physical capabilities, filling more feeding niches, their digestive systems were becoming more efficient, more “organ-ised”. In fact, adult lampreys are an extreme case; they latch onto the sides of fish and suck out their blood and tissues.

A British marine zoologist active in the first half of the 1900s, Walter Garstang, wrote poetry to help his students remember some less than elementary biology. One of his poems mentioned “my” ammocoetes. I liked and sometimes recited that part of the poem; but I proved him wrong though. He wrote:

> Now look at *Ammocoetes* there, reclining in the mud,
> Preparing thyroid-extract to secure his tiny food:
> If just a touch of sunshine more should make his gonads grow,
> The lancelet's claims to ancestry would get a nasty blow!

Ammocoetes, I discovered, use a primitive pancreas to “secure” their food, not a thyroid.

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My instructor was pleased with the work—I was now a B. Sc. (hon.)—and used it to lever me out of his lab and into the Zoology Department of the University of Queensland in subtropical Brisbane. There, during 1966-1968, I studied various aspects of the prawn, or shrimp, fishery in Moreton Bay toward a Master of Science degree.

The field work was my first marine research and very demanding. There was a long drive to the Quarantine Station at the head of the Brisbane River, where the university’s leased prawn trawler, the Wanderer, was moored. The skipper, Les Wale, was a giant of a man, always incredibly jovial and with a head full of jokes. Several nights each week we headed out into Moreton Bay, trawling among the prawning fleet to get an idea of what and how much was being captured on the Bay’s muddy bottom, returning at dawn. Often I would have to go straight to the university where I worked part time as a “demonstrator” (of laboratory techniques) in the students’ laboratory.

The trip to the Wanderer of an afternoon always filled me with a mixture of excitement and apprehension. On the one hand, it was quite an adventure, leaving the shore, steaming down the river and trawling around the bay in the dark, with lights of other boats and warning buoys looming near and fading away, generally stars above, and often seagulls behind; and below, who could say what the net would bring up. On the other hand, if there were much of a wind I would be sick as a dog—well, much sicker; I had a young dog who always came with me and never showed any discomfort.

Les and I took turns to try to nap during the trawl itself, which was generally about an hour in duration. An electric winch brought the net up over a tray on the deck and the catch was dumped onto it. The Wanderer, about 35 feet long, was a narrow beast, and rolled to an unnecessarily sickening degree when we hove to, to bring in the net.

The catch was generally a biologist’s delight in the diversity of marine life that spilled onto the tray. Usually there were dozens of different kinds and sizes of fish and crustaceans (like shrimp, crabs) and echinoderms (sea stars, sea urchins, sea cucumbers). It was a bewildering sight. It took me several weeks to familiarize myself with the names and affinities of the fish species so that I could begin to analyse the catch adequately.

Then came the work of sorting the catch on the pitching deck. Sometimes it might include an angry turtle with dangerously strong flippers lashing out. Or the net might fill up with large jellyfish that had to be handled carefully to avoid being stung. And there were always plenty of other dangers in the catch. Stingrays had venomous spines in their tails that caused severe pain and were known to kill humans. “Happy moments” were small rabbitfish whose dorsal spines sent a nasty pain like an electric shock through the body when accidentally touched. The dorsal fins of lionfish and the hidden spikes behind the head of catfish caused excruciating pains. Sea urchin spines could bring tears to the eyes when touched; and the spines broke off inside the fingers where they remained a painful annoyance for days. A sea snake would have us jumping away from the sorting tray.

And despite Les's high spirits, I was nearly always seasick to some extent. A strong sou'easterly would soon have me heaving over the gunwales, but even a gentle swell was enough to make me queasy. Les revelled in the conditions and sometimes I'm sure he lit his pipe just to watch me turn green as he puffed smoke toward me. All this adventure and agony appeared in my Master's thesis in one sentence: "Most specimens…examined in this investigation were captured by bottom trawl in various parts of Moreton Bay during 1966 and 1967."

I decided to focus on the biology of the most common commercial fish, locally called the winter whiting, being taken in the prawn by-catch. This entailed less frequent trawling trips and more intense laboratory work, measuring and weighing the fish, taking and cataloguing scale samples, measuring and inspecting the condition of the gonads, measuring egg sizes and looking for growth rings on the scales under the microscope.

Aquaculture, or fish farming, was being explored as a new way of meeting the demand for seafood in Australia about this time and for a while I was distracted by attempts to keep whiting alive with a view to breeding them. My supervisor was much against aquaculture; he saw no future in it as a commercial proposition. At the present time, I can smugly point out, aquaculture production makes up some 40 percent of global fish production! However, I was in no position to argue with a supervisor.

In those days, aquaculture in Australia was nearly all theory, with little practice, other than oyster farming—which required little more than putting out poles to attract the young oysters (spat) and letting nature take its course. Later, I wrote a book on *The Potential of Aquaculture in Australia*, published by the Department of Primary

Industry in 1975, which I think played a small role in inspiring the industry there. Later, it was to help realize my tropical dream.

My research did generate new knowledge about the prawn fishery and the whiting in particular. Winter whiting, I discovered, were more tropical than temperate in behaviour, unlike other members of the whiting family, and fast growing; each female fish spawned maybe four times a year, although living for only a few years. The overall spawning "season" appeared to cover most of the year apart from autumn (March-May). The whiting were opportunistic carnivores, that is, they ate whatever was common at the time, from small bivalve shellfish to small crustaceans to small fish. Later researchers have referenced the study also as one of the earliest records of the quantity and diversity of fish caught and thrown overboard during prawning operations—the by-catch that is wasted. The waste from trawlers was to become a major bone of contention between conservationists and fishers around the world.

Some of the other researchers at the university were working on the Great Barrier Reef and in their subtropical laboratories at the university there was a sense of the real tropics. Crown-of-thorns starfish were a new menace devouring the Great Barrier Reef and a hot subject of research and opinion. But it was a tank of bright yellow butterflyfish in one laboratory that crystallized and brought into sharp focus my own desires. These beautiful and delicate fish gently moving around the tank with an air of innocence and mystery simply hypnotized me; so unlike the goldfish that grubbed around aquaria in Sydney. I had to see them "at home" on the tropical coral reefs where they and many similar species lived—I would be a marine biologist living and working in the tropics.

One tangible result of this conviction was that, during these research years, I decided to, and began to, build a boat that would be my ticket to the Great Barrier Reef and then Papua New Guinea. The yacht was to be home, office and laboratory for a life in the tropics.

I certainly didn't have the wherewithal to buy a yacht. However, I began to take notice of a new generation of sailors building ferroconcrete boats that were cheaper to build and simpler to make than wooden, steel or fibreglass boats. The more I read the more excited I became and began to visit a boatyard where ferroconcrete trawlers were under construction.

I engaged a naval architect to make some plans. He and I decided that my boat should be 49 foot long with a shallow draft—for cruising among coral reefs—and be a ketch, which could be handled by two persons or even one in a pinch.

Over the next three years, while gaining knowledge about the prawning industry and the winter whiting, I was also learning all the skills involved in ferroconcrete boat building, from reading and scaling-up architect's plans to bending pipes accurately to arc welding regular and stainless steel, concrete plastering, marine engines and seals and shafts, antifouling paints, and so on.

When I graduated as a marine biologist with a Masters degree at the end of 1968, the boat was still on land; masts, rigging and sails were not yet on the horizon. In their place were a wife and a tiny daughter.

Brisbane at that time was a dead end careerwise. There were no jobs in fisheries or marine biology to apply for, so I took on casual labouring positions found at the local government-run employment office. I was on the "dole" for several weeks during one low period. That to me was the horrifying bottom of the barrel, being the breadwinner for a family (my father as the role model). At the time, an unemployed person would receive about $30 per week. We were paying $20 of that for rent in an old Brisbane-style house on wooden stilts beside the railway line at the time. I felt much better, at least I had some dignity, when I was tying wire netting to gate frames or moving steel girders around a factory at the casual labour rate of $37 per week, although not much more lucrative than the unemployment benefit. I even applied for positions in biochemistry, in which I was qualified, but really dreaded the prospect of life in a biochemistry laboratory away from the sea. It probably showed in my applications.

In frustration, I became quite vocal in marine circles about the lack of career opportunities on the ground vis à vis the glossy brochures put out by the Commonwealth Scientific and Industrial Research Organisation, or CSIRO, which had a large Fisheries and Oceanography Division and was the largest potential employer; the Australian Marine Sciences Association through its newsletter also hinted at a wide range of research and the need for plenty more.

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Surprisingly, in those faraway days before computers, news of my daring to point out the hypocrisy of the marine science career situation travelled fast, with one state fisheries director declaring I would never get a job in fisheries. The news even reached Canberra, and with a more sympathetic response. Out of the blue I had a phone call from one Albert Caton to apply for a job in the division where he worked—the Fisheries Division of the then Commonwealth Department of Primary Industry.

I did apply, passed the entrance exam, and was offered a job at entry level, with the uninspiring title of “graduate clerk”. By January 1970, I was in Canberra as a government fisheries employee—but the yacht construction had to be abandoned and the hull sold. It was an utmost wrenching experience; so many hopes and dreams that were on their way to fulfilment were lost virtually overnight. I had lost my ticket to Papua New Guinea.

I was now a long way from the fish and the sea, particularly the tropical seas. Albert became a firm friend and source of support during my restless time in Canberra and beyond.

In the Division, there was, nevertheless, interesting work both locally and internationally. The international aspects related to how much sea Australia could grab under the new United Nations Law of the Sea Convention. You had to establish a—I nearly said watertight—case that would stand up in international law and that meant knowing all about the resources, that is the fish and crustaceans and molluscs and what have you in the sea and on the bottom, which is where our unit came in, to give advice. It was also useful for international or bilateral treaties, in which foreign fishing fleets were allowed to fish inside our newly-declared exclusive economic zone that extended 200 nautical miles to sea.

Months or even years of negotiation went into these treaties or agreements, hammering out how many fish could be caught and where and when. The foreign interests came up with wildly optimistic estimates of how many target fish were there for the taking, and we would respond with wildly conservative numbers. It was a huge charade, of course. Once the foreign interests had signed the necessary papers they went away to fish as much as they physically could out of the stocks. One of the prime targets was southern bluefin tuna, beloved of the Japanese sashimi (raw fish) trade. Long after I left the Division, Albert wrote to me that "Southern bluefin tuna still cling to non-extinction but we are working hard to get the better of them. If the management regime is as difficult for the fish as it is for the fishermen, they'll die of frustration".

The rest of the time we gave advice to non-hearing career-oriented senior staff on what to say at regular meetings between federal (us) and state (them) fisheries officers. These briefings had to be less than two pages of triple-spaced words in large type and usually consisted of several bullet points, such as "best not to speak on this matter", or "we should reserve our position", or "Australia is a large continent surrounded by the sea", and once (to find out if they actually looked at these briefs) "the species in question is in fact a subspecies and is distinguished by the dense setae on the maxillipeds, the length of the telson and the truncated anal spine". The statement was used in the meeting but, alas, in response to a question about the new federal fisheries minister.

One of the highlights of those lighthearted days was a visit to the Gulf of Carpentaria—the tropics at last—at the height of the prawning season to help in an economic survey of the industry. The thrills began with my first flight in a small plane, from Cairns—itself tropical—to Karumba, one of the few landing ports in the Gulf. The airline name, Bush Pilots, should have warned me, but the Government wouldn't send me up in a dubious aircraft, would they? I sat beside the pilot and watched in awe as we roared down the runway and climbed slowly into the sky. The noise made conversation impossible so I gazed around in something of an ecstasy until my gaze met the dashboard. Even a car driver knows to check the fuel gauge now and then. There were two on this plane, one for each engine and one was showing empty. Looking behind the wing, I could see a white spray of vapour that might explain why. Ever so casually, I tapped on the gauge until the pilot noticed what I was doing. He turned white and the plane went into a stomach-heaving turn as we headed back to Cairns.

With all sorts of guarantees on aeroplane performance, I was induced to climb in again after the repairs and refuelling had been done. The trip was technically uneventful, and I would have almost preferred death to missing the scenery that passed beneath us during the few hours of the flight. After flying across the green coastal fringe of the continent, we were suddenly over semi-desert. I had never seen before such a desolate yet exciting landscape. It was an Australia I had seen in pictures and words, but to see the endless dry scrubland sliding under the plane was almost a culture shock for one city-bred and beach-wise. The scrub became more and more sparse, virtually real desert, and then green snakes of mangroves that marked narrow creeks began to appear in the beige terrain; the snakes became bigger and more numerous, all winding but generally heading in our direction, the Gulf. It was beautiful, alluring, and at the same time, the last place on earth I would want the plane to crash. If I had known that I would soon almost be marooned in one of those snakes, I would never have reboarded the plane.

In Karumba, I teamed up with some other staff from Canberra and we made our rounds of the boats. It was a bonanza of a fishery, based on tropical banana prawns, which, unlike other kinds, gathered by the thousand in huge underwater balls for their reproduction, massive nuptial dances that could be easily seen by spotter planes. The prawners came limping into the port, their holds swollen with their catch—there was no bycatch and so no tedious sorting as their counterparts in Moreton Bay did—and the big yellow prawns were sucked out onto a conveyor belt and sped straight into a blast freezer for export.

As a budding scientist, I was invited to join the CSIRO's larval prawn sampling seaplane on one of its inland trips. Their research team had discovered that the baby prawns or larvae migrated upstream; sampling the creeks to find out how many baby prawns were there would enable the researchers to predict whether there would be a good or bad catch the following year, which was when the prawns approached maturity and migrated out into the Gulf to breed.

If the Bush Pilots flight was exciting, this was beyond expression. The single-engine float plane roared down a broad mangrove-lined creek—it was the mouth of one of those snakes I saw on the way from Cairns—and drifted noisily up into the haze, following the general direction of the snake. We turned and visited several other snakes and, after about 15 minutes, pointed down toward a writhing and horrifyingly thin one. How the pilot found this sampling site in the maze of intertwining identical creeks was a mystery.

Then the plane went into a series of tight circles with one wing almost vertically down.

"What are we doing now?" I was compelled to ask the scientist beside me, fearing I might fall down through the open window.

"Looking for willy-willys", he shouted back.

"What?"

"Last year, the previous seaplane we had crashed into one of these creeks as it was trying to land. There was a small willy-willy—a whirlwind—in the creek; it flipped the plane over and it went into the mangroves upside down. The pilot got out ok, but the scientist broke his back."

I tried to imagine how one would help a severely injured person in a crocodile-infested creek a long way from anywhere and no means of communication. How many hundreds or thousands of kilometres was it to a hospital? I opened my mouth to ask these questions but thought better of it and concentrated on looking for the whirlwinds. We saw one, visible because of the dust cloud it formed; I could see what a hazard they were, but it was a grim way for the research team to find out.

The pilot flew a little way further along the creek made another tight circle that brought us down to tree height and then we were skimming smoothly on the creek surface—while I clung to whatever piece of the aircraft seemed least likely to fall off if we crashed. The mangroves shot past dangerously close; the creek was hardly wider than the wings.

Once in the creek, the plane became a boat. It was steered by small rudders at the back of the pontoons. The sampling technique was simply to tow a net behind it to catch the baby prawns. By towing it for the same length of time at the same speed on each occasion in each sampling site, the relative amounts of prawns in each creek during the season could be determined. Our scientist climbed down onto one of the pontoons, tied on the net and the pilot revved the engine.

We drifted into the shallows and as the plane eased forward, a stray mangrove branch caught the wire that operated the rudders. Snap. The wire was torn off and the plane became nearly as useless in the water as a boat without a rudder. The sampling was aborted but all was not lost. The aerial rudder on the plane's tail would begin to function as we sped up. There would be no problem when we got close to take-off speed. The problem was how to keep the plane out of the mangroves that were reaching out mere inches from the wingtips until we reached that speed. By gunning the engine in bursts, the pilot managed to keep the plane moving forward, scraping the wings unnervingly on branch tips as we weaved along the creek. We reached the spot where we had landed. It now looked comparatively wide and, with a "hang on", the pilot immediately opened the throttle, the plane leapt forward with a roar and we were airborne in a mercifully few seconds. I suspected that the pilot was being overdramatic about the danger of the situation but he sure threw caution to the wind taking off. We might have flown head on into a willy-willy.

Despite its hazards, the trip made me restless. The Gulf of Carpentaria was in the tropics, albeit very different from the tropics that had taken shape in my mind as I worked on the yacht frame in Brisbane. But it was nevertheless exciting and a far cry from the manicured lawns and streets of Canberra. The trip rekindled the embers of my tropical marine biology dream. And the hazards of flying in small planes in the tropics seemed far preferable to dodging the territorial magpies lurking in the trees of Canberra's parks.

So when I saw a vacancy for a fisheries researcher to work in Papua New Guinea, I was compelled to apply. Not only was it in the "real" tropics, set among coral reefs, but also the work was on marine aquaculture. The task was to determine the prospects for oyster and pearl oyster farming there. The position was a "secondment", that is I would be lent by Canberra to the then Australian colony for an indefinite period, initially two years, after which I could return to the public service in Canberra, with no loss of seniority or benefits. My wife agreed with the idea; our children—there were two by then—were too young for schooling to be an issue; and she was interested to see the colony. The application was successful.

Tropical Life

At last we turn now to the seat of the story, the tropical western parts of the Pacific Ocean, where, in early 1972, I was on my ambitious way to develop oyster farming and pearl culture in a country where red tides were not even a remote consideration, blissfully unaware of the great weight of human, pearl farming and red tide history about to bear down on me.

"You are to begin work in Port Moresby as a Biologist, Fisheries, Class 2, of the Department of Agriculture, Stock and Fisheries of the Territory of Papua and New Guinea, effective 14 February 1972". So read my appointment letter.

Just over two years after we, my family and I, had left Brisbane and the half-finished yacht that I thought was my only ticket to Papua New Guinea, we landed in Port Moresby. It should have been cause for a great celebration—a vindication of so many dreams, the fulfilment of my prophecy, the revival of the notion to live on a yacht, and the prospect of cruising among a wilderness of coral reefs and wonderfully collared fish, as well as working from a floating office.

But the first and overwhelming impression was of incredible heat. The temperature difference between very temperate Canberra (via airconditioned airports and aeroplanes) and the tarmac at Port Moresby was a zillion degrees. It was truly oven-like. The dry heat of Karumba I experienced the year before raised no alarm bells about tropical life. But this was the humid tropics. How could people survive this debilitating heat? The immediate answer was not to stand long on sunny airport tarmacs. Shade and breeze relieved some of the heat stress but not all. It took months of acclimatization before we were comfortable to any extent.

We were driven straight to our allotted house in a subdivision called Gordon's Estate. My heart sank again. As if the heat were not enough, we were confronted with a fibreboard shoe box on 10-foot high concrete stilts among a long line of similar boxes beside a narrow dirt road. The walls consisted mainly of louvre windows, with a front door in the centre of one end atop crude front stairs. There was a second exit—but not entrance; this was an escape hatch in the bedroom. If you needed to use it, you jumped or fell to the ground. The ground was dirt.

The fences between the houses, where they were present, were hedges of hibiscus, easily crossed by neighbours and burglars. There was no ceiling, for air circulation purposes, aided by a few overhead fans; the house was divided into a front lounge-dining and kitchen area, behind which was a rudimentary bathroom, and three bedrooms, one of which was hardly big enough for a single bed. With two children and a third on the way we not exactly overjoyed.

But it was now home. The allotted shoe-box house was standard accommodation in the territory at that time and we had to make the best of it. The first, pressing task was installation of an air conditioner.

The next, delicate, job was to find some house help. You needed someone in the house more for security purposes than to look after a 60 square meter box. Some houses in the street had been robbed. By the end of our stay, ours was the only one among about two dozen that had not been not robbed, mainly because there was nearly always someone at home.

And it would be convenient to have a helper, with our baby expected in a few months. Plus, we needed someone trustworthy; generally, expatriates were considered fair game. Having help also meant a crash course on the islands' lingua franca, Pidgin, a mixture of bastardized European languages and native words that had evolved into a language understood and used widely around the South Pacific.

An incidental spy

My first sweaty interview with my new superiors in the territory painted my terms of reference in a completely different perspective. I had armed myself for a discussion on what research I might carry out. But after the opening pleasantries by senior staff and ordering tea or coffee, the department's agricultural research director took the floor and his first sentences left me open mouthed. "Actually, the main reason we asked for a mollusc biologist was to keep an eye on the Japanese pearl farm in Port Moresby Harbour," he said nonchalantly. I gripped the arms of my chair as he explained the situation.

"As you know, the Japanese are the only people who know how to make pearls; wherever pearl oysters are being farmed, you will find Japanese technicians in control. They are setting up farms around the Pacific. In Port Moresby Harbour, under our nose, there is a Japanese company that has been bringing in pearl oysters from Western Australia since 1965, and turning out pearls.

"We have had no formal contact with them for several years and although there is some paperwork on file, we have no real idea how many pearls they are producing or what else may be going on there. They have a lot of rafts and local divers working under them. Some villagers have reported being roughed up when they got to close to the farm in their canoes. The police are not interested unless someone gets killed; they have their hands full around Moresby without looking for work down the harbour.

"The pearl farm is isolated. There are no roads and it is more or less cut off from the rest of the harbour; you can only approach it by boat. For all we know, they could have a mini-submarine base in there. It's unlikely, of course. We couldn't tell Canberra about our concerns because an official enquiry would damage political relations with Japan and if it is a genuine pearl farm, we need businesses to thrive for the territory to get on its own feet. Rumours are that the territory may get its independence sooner than we would like."

I looked out the window. The brown hulk of the MacDhui, a freighter that sank in shallow water under attack from Japanese aircraft while waiting to take on soldiers during World War II stood out in the placid harbour waters. On the outer reef of the harbor, the monel metal propeller of a Japanese Zero fighter aeroplane glinted in the sun. The sides of Moresby's airport runway, I remembered, were lined with bunkers for wartime aircraft. Later, I was to see numerous landing barges from the war rusting against shorelines and draped over reefs in the harbour and wherever I dived around the territory.

Japan occupied the north of the territory during World War II, setting up an elaborate base in 1942 for its Pacific operations in the magnificent harbour of Rabaul on the northern island of New Britain. Many Australians and Japanese died in the battles to regain the territory.

I looked back at the director. His hands were trembling; as we drank our coffee, his cup rattled against the saucer. Looking the worse for alcohol, he probably fought here as a youth during the war, I thought. This was probably true of other senior government staff. They were all Australians and the war, while distant in time, was present all around them.

Not only was the past uncomfortable, the future was looking ominous too. Tensions between Australia and the territory, and consequently between expatriates and locals, had been building since the late 1960s as a result of Australian political confusion on the one hand and actions by the territory's House of Assembly on the other.

In Australia, the opposition Labour Party was pushing for near-term independence for the territory and its leader (Gough Whitlam) was making speeches to this effect both in parliament and in the territory itself. This certainly had a galvanizing effect on local politics, which became polarized into a conservative group that thought they were being abandoned by Australia, which provided a huge amount of funding to the territory each year; and a proindependence nationalistic group eager for an early separation from the colonial masters, though not from financial assistance.

Meanwhile, a House of Assembly committee set up in 1969 to determine the mood of the people with regard to independence reported in 1971 that the territory should work toward self-governance during the term of the 1972-1976 House of Assembly. The elections for this House of Assembly began in the month of our arrival and by the end of March 1972 a coalition majority group had been formed, with its leader, Michael Somare, intent on bringing self-government and independence to his country. The word "territory" was struck from the country's name.

Against that background, the country itself was the antithesis of orderly and well-developed Australia. The coastal areas and parts of the New Guinea highlands were more or less stable and accessible by road, aircraft or boat. But elsewhere in the mountains there were still unknown numbers of undiscovered (that is, to the government) tribes. The fact that there were more than 800 languages spoken by only a few million people in total gives some idea of the fragmentation of society and difficulty in communications—and governance.

Reading between the lines, I realized that the expatriates running the territory felt somewhat betrayed. They were helping to build up an embryonic economy and some had even fought for it, seeing it as part of Australia. And now it was being given away, still undeveloped, with the risk that another country, maybe Japan, might step in again and take control.

They only had to look next door. Just 10 years before, the western half of the island was being prepared for independence by its Dutch governors when the Indonesians invaded and turned it into an Indonesian province.

The interview ended with some desultory discussion about oysters and research facilities. I left with my lofty research ideas in tatters.

Living in Port Moresby

With research on the back burner, I was at able to focus on getting the family settled. After a week in the territory, I wrote to my friends in Canberra, discreetly not mentioning my spying role:

> "I have been here one week and so far it's not so bad. Probably you'll find it hard to comprehend the conditions up here, but they add up to fascinating.
>
> Our house is a six-square box on stilts with no windows at the ends, louvers on the sides, two small bedrooms. Lots of burglaries around, mainly cash and knives; a nearby house has been entered several times by axing in the fire escape built into the bedroom floors. We're not discouraged, except that my wife wanted to catch the next plane, her feeling aggravated by the extreme heat, the price of food—significantly dearer than in Australia; fruit is imported and the prices prohibitive. But Japanese radios and cars are cheap. Everyone has either a Colt or small Toyota, which start around $1,450. Second-hand car prices are inflated because the locals can afford them, if you see what I mean.
>
> We have a "boy" to work around the house; we got tired of telling the dozen applicants each day since we've been here "no got work", and he has become very territorial and fends off newcomers, besides which our furniture just arrived and there are over 50 boxes and a couple of dozen even larger enigmatic crates to sort through."

Our "boy" was Omen. His favourite work was to polish the wooden floor on his hands and knees with our 2-year old son riding on his back. Most of his earnings went into the purchase of bird-of-paradise feathers as part of the bride price for the girl he wanted to marry in highland Goroka.

One day, he honoured us by bringing along an old schoolbag for us to hide in the house. When he opened it, we gasped at the mass of long and short plumage of all kinds of colourful birds-of-paradise. It was full of these incredible feathers. Our gasp was half dismay at the thought of the number of birds that must have been slaughtered to make this dowry. Omen was grinning widely. I guess he thought he had greatly impressed us with his wealth.

Omen slept with wontoks, or persons from the same tribe, under a crude shelter somewhere in the nearby hills and would sometimes arrive with a bleeding scalp where rats had scalloped a little skin during the night. My wife would tend to the wounds.

Security was an early concern. This had to be dealt with by official letters of the type that only public servants can write to each other:

> "To the Executive Officer. Property and Accommodations Section, Box 327, P.O. Port Moresby.
>
> Dear Sir, I have recently moved into an administration house at Lot 71, Section 104, Gordon's estate. As a biologist I shall be required to spend a good deal of time on field work out of Moresby, and in the interests of safety for my wife and two children, I would be grateful if you would install "security wire" on all the windows of the house as soon as possible.
>
> I understand that electrical problems should be addressed to you rather than to Elcom…."

Security wire meant fencing wire to prevent thieves entering by simply breaking a few louvers. It was also called "boy wire," in reference to the usual source of the problem.

Health was another concern for a young family new to the territory. In the letter to Canberra friends about our first week's experiences, I added:

> "Everyone is well except my wife who has anaemia, my daughter who is developing bad heat rash, and my son who

> has been to hospital three times and the doctor twice with fever and now apparent dysentery, and myself who blew open an artery in the wrist on a sharp rusty wire trying to start an outboard motor. Sort of spoilt the field trip but while spectacular at the time is healing although still may need a stitch or something."

Children's ailments were a real problem in those early days. In a letter to my honours degree mentor written a month after we arrived, I wrote:

> "Initially, lack of a vehicle was a nightmare. Fortunately, we were able to borrow the neighbours' sedan. Fortunately, because our 2 year-old son nearly died about a week after arrival here. He went down with some tropical bug, became dehydrated, and was prescribed too heavy a dose of an anti-sickness pill. We raced him to hospital at three in the morning, by which time he was semi-rigid; breathing seemed to stop twice. He bounced back after several days in hospital and the antidote, but last week was at the doctor's every day with another illness. Yesterday he began to brighten again. Our fingers are crossed.
>
> Even our hardy daughter had a bout of high temperatures and sickness. Something appears to have caught her yesterday. We were up to her last night in the early hours with diarrhoea.
>
> Meanwhile, work is pleasant…"

We arrived at the beginning of the rainy season, and the rain too was a psychological drain until the monsoon ended in May—and then things became tinder dry! In one letter, I mentioned: "We had 4 inches of rain the other night. But it passed without comment—just a shower. Rains every other day still, little thunder though."

In May, our second daughter was born. The hospital's labour ward was something to remember. In the next room to ours were two local women who gave birth while we were awaiting our baby. They put on a great performance of wailing and carrying on. One insisted on staying under the bed rather than on it, which caused much argument in high-pitched pidgin and Motu (the main New Guinea language), and helped my wife forget her own labour. But when our baby arrived there was just me around. I was most surprised when I saw a head appear and by the time a nurse arrived the baby was nearly out. I was praised for my gallant role, which was mainly that I didn't faint. Two local nurses tied off the cord very efficiently and all was well thereafter.

Recurrent illnesses were so common that they rated brief mention in my subsequent letters to friends in Canberra. A letter four months after our arrival mentioned that everyone at home was sick except our 3-week old daughter with colds and conjunctivitis and sundry infections.

Malaria was a large problem; we began taking malaria tablets several weeks before the trip and continued to take them throughout our stay in the territory. There were dangers. The tablets then were chloroquine, a derivative of quinine, and had such long-term side effects as blindness. Chloroquine tasted like the ultimate poison, so there were endless battles and ploys trying to get the tablets down children's throats twice a week—disguising them inside bananas and grinding them up in sweet drinks to name a few of the less direct approaches.

Tropical ulcers, which we were mostly spared, were only too common, in expatriates and locals alike. They were small wounds that became large ghastly craters in the skin that you could poke a finger in. The locals suffered terribly; a strong dose of expensive antibiotics was needed to heal them. A fresh ulcer would turn you off breakfast for weeks; they weeped various fluids, from clear lymph to robust puss, and attracted flies from the outer islands. Cured, the ulcers tended to leave prominent and permanent scars, so I could see the wide extent of their incidence among local residents.

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Large supermarkets were yet to reach the territory. Much of our shopping was done in the ubiquitous Chinese stores where, like the one in Steinbeck's Cannery Row, you could literally buy almost anything. Many of them had been around for decades and accumulated all manner of paraphernalia stocked in every nook and cranny.

At our favourite Chinese store, you could buy merchandise from bread to buttons, watches, all manner of electrical equipment, beer, most other alcoholic beverages, clothing, toys, and tons of what I would call mysterious Chinese goodies that you could ponder over and bargain for. In this category were items ranging from stuffed animals to sculptured pearl shells to richly ornate writing desks, glory boxes, tables, etc., even Peruvian pig skin-covered lute-type instruments. Also there were packets of what the labels would indicate were aphrodisiacs from the organs of what the Chinese considered were exceptionally virile animals, chiefly drawn from their zodiac; and always there were salted plums and dried mango in big jars. We bought a large amplifier and stereo system, from among the dusty shelves of plastic-covered appliances.

A car really was essential and not only for shopping and occasional dashes to the hospital. The research station at Kanudi where I was to work was about 10 kilometres away across a dusty gravel road that passed by the national university campus, and then along the back of Port Moresby Harbour. Kanudi was about half way along the harbour and the road continued on to the main town. Most other expatriate personnel of the station were living in on-site housing, so car pooling was not an option.

I was able to find an aging Volkswagen Beetle that looked a lot worse than it performed, fortunately. And the trip to Kanudi was usually enjoyable. The Beetle's front-wheel drive made for wonderful slides around the bends—the rear wheels easily lost their grip at moderate speeds on the corners while the front wheels held their track and the car would drift crabwise around the corners.

However, that kind of driving was only for unpopulated areas. Elsewhere, driving was generally a more cautious business. Some enterprising villagers had taken to throwing dead animals, usually dogs, onto the road as a car approached; a group of them would stop the car as it passed the dead animal and they would demand compensation "payback" from the driver for running over the animal and killing it. Toward the end of my second year in the territory, a Fijian doctor was murdered on one of Moresby's approach roads. Apparently he was unaware of the nature of this ploy and refused to pay.

In fact, there was an area for very cautious driving along that road between Gordon's Estate and Kanudi. At one point there was a harbour-side village spread out above the road and almost opposite it a village on a small island, Tatana, connected to the shore by a causeway. Once, driving my visiting mother to show her the research station, we turned a corner to find the two sets of villagers shouting and taunting each other, separated only by the road. They had spears and shields and various improvised weapons and were clearly bent on a little action. The beetle nosed into the side of this confrontation before I could stop.

Both groups were of tall Papuan tribes; the "warriors" seemed to tower over the beetle. Someone waved us on and obediently I edged the car forward—into the middle of the melee. The noise was frightening enough; the anger on the faces was worse. Some of them ignored us, bent on shouting abuse over our roof at each other; others peered malevolently through the windscreen and side windows.

"What are they doing, dear?"

"Dancing, Mum."

"Oh. Do be careful; they haven't left us much room".

"I will certainly try at all costs to avoid bumping them, Mum".

“They look terribly fierce”.

“Probably practicing a war dance, Mum”.

By this time we were approaching the other side of the mass of assembled villagers. The atmosphere was incredibly tense. I clung to the wheel with my arms, head lowered as if to avoid a swing from a club. My mother gazed around approvingly. Suddenly, someone banged on the roof of the car. That was enough for me. I gunned the engine and we left the outliers in a cloud of dust.

***

When it came to music, the territory was a desert. The Port Moresby radio stations played local favourites, of which there were many, all indistinguishable from one another, apart from slight variations in speed. Best described as a kind of strangled country and western music—and that is already saying something—all the songs began with a descending wail of sorts that landed on a chord based on the 4^{th} note of the scale. Since practically all songs were in the key of E, the easiest on a guitar, they began in A and on an invisible signal known to some of the band members, fell, tumbled or were pushed down to the root, E. After a decent interval of singing and practicing strumming on E, the song would stumble down again to B, the dominant chord; or it might surprise one entirely—the singers always sounded surprised as well—by tackling the A chord again. But the outcome of these variations was always the same; a painful retreat to the E root. Generally there was a pause, to recuperate I expect; then the wailing was taken up again and the chord sequence repeated.

I came across a similar wailing once at the airport in Losuia, capital of the Trobriand Islands. Picture the old twin-propeller DC3 leaning back on its rear wheel in a paddock-like clearing, bordered by a crude brushwood fence, a few locals in loin cloths sitting or squatting in the shade, chatting and smoking; a small thatched shed, 44-gallon drums of fuel and whatnot lying around the perimeter of the clearing. It is sunny and quiet. Only mad dogs and…sure enough, the peace is broken by the wailing of an Englishman, head down on the fence! He is practically screaming. He is in a Trobriand loin cloth too. No one appears to notice his incredible display.

After a while, curiosity gets the better of me. I saunter over into the sun. "Hey, are you alright?" I have to repeat it because he is wailing so, so loud. He stops abruptly.

"Oh, hullo. Yes, I'm fine thanks. My wife's from here and she's off to Moresby on this flight. This is just the way the villagers farewell someone close when that person is leaving."
"I'm an anthropologist", he adds apologetically.

He points with his nose to a tree, under which a few locals are sitting, chewing betel nut.

"My in-laws are watching so I have to give it my best."

He smiles and immediately breaks out into another wail so loud I run back to the shade. I think the in-laws have the right idea.

The highlanders more traditional music was revealed to me at a party in Moresby one late night. It was in a bare room in almost complete darkness. There were semicomatose bodies all over the floor. Treading over and around them were two men from Mount Hagen, playing flutes *at* each other. The flutes were simply one node of a large bamboo branch, open at one end and sealed by nature at the other. Near the sealed end, an inch-square hole had been gauged out, where the performer blew to make the sound. There was only one possible note with normal blowing, which was exhausting enough; I gave up after only a few notes, but by really blowing hard, a higher pitch note was possible. Apart from that 'range', a waah-waah, or was it woo-woo effect could be made by opening and closing the open end of the bamboo with one hand. The two men faced each other one step apart and, staying in step went backwards and forwards across the room and bodies. Seen on a stage at a theatre, one would wonder at the weird imagination of the play's author. Witnessed in a dark private room in Port Moresby, it was a mysterious opening into a timeless culture. It sounded horrible!

At parties with electricity, the record players and latest Dolby cassette players were turning out the sounds of the enduring rock band Pink Floyd, whose LP (long-playing record—a 12 inch wide disk of vinyl, I feel obliged to add)—Obscured by Clouds was the sound track of a new (1972) movie called La Vallee, set in PNG.

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The working week at Kanudi evolved into several regular field tasks: sampling the tiny animals and algae that drifted in the seawater, taking readings of water temperature, gathering water samples for salinity determination, checking spat (baby oyster) collectors, and checking on pearl oyster cages on the bottom. In the red tide season, almost daily checking for tell-tale organisms in the water column was another ritual. I shared these tasks with my two local assistants. Deep diving was done by me and my Australian assistant Jon Peters; in busy weeks I might be scuba diving in the harbour four days a week. (Learning to dive was an experience in itself, described later).

You might think that with a regime like that, weekends would be spent as far from the sea as possible. But the attraction of tropical reefs was magnetic, addictive. All my youthful dreams of actually being a marine biologist in the tropics had come true and I never lost sight of the fact.

On one or other morning each weekend, Joe Glucksman, who was one of the scientists at Kanudi, Peter (Joe's Australian research assistant), and I would take the station's aluminium dinghy and race off to unexplored dive locations outside Port Moresby. In those reckless times, we usually had a cooler of beer on board and knocked off an SP (South Pacific) brownie (small bottle) each before the dive.

One Sunday morning, we decided to dive the east wall of the harbour. The boat was tied to a coral head and after our beer, down we went, drifting seaward in a moderate current with no dive plan other than to dive again the next week. The water was clear and blue, the wall beside us dropping down in rocky steps between sandy ledges. How long we drifted down we will never know. We levelled off on a wide sandy ledge where I spied a giant grouper ahead of us. I actually had a new depth gauge on that dive; it worked by pushing a bubble of air along a tube which was wrapped around a dial. The numbers on the dial became closer together at increasing depth, but I figured, when I looked to see how deep the grouper was, that we were nearly 60 meters down, nearly three times our usual diving depth! My reaction was one of pleasant surprise; we had reached a depth record and it had seemed so easy. I finned ahead and photographed the grouper with our Nikonos II.

Then I turned to signal my two buddies in case they had not seen the fish. Joe, the nearer, had dropped his regulator from his mouth and was staring vacantly into Big Blue; Peter was several meters away drifting at a strange angle. I was dumbfounded. Was it a joke? Rushing over to Joe, I jammed the regulator in his mouth and purged it, blasting his mouth with air for several seconds while I banged on his mask. He came to and looked at me in surprise. I thrust an upraised thumb at his mask—go up, quickly. He nodded vaguely. I pushed him upwards and watched as he began to fin slowly away from me. It was no joke. Then I finned madly across to Peter who had by then drifted downwards some distance away. His eyes were shut and I really thought he had died. Why, I did not know at the time, because, as we later realized, I was also suffering from the same symptoms—raptures of the deep; narcosis—but fortunately to a lesser degree.

I grabbed the front of Peter’s wetsuit and began finning upwards with him as fast as I could. Our progress was slow, which was lucky in the hindsight of later knowledge of diving physiology that tells us a too-rapid ascent will leave bubbles in our blood that result in the bends, but he regained consciousness at some point in the ascent and I was able to relax a little. The rest of the journey to the surface nevertheless took several long minutes, during which I willed Joe, somewhere out of sight in the sea near us, to the surface. Reaching sunlight, I looked around me in panic. Joe was nowhere to be seen. Where was he? I left Peter with his own unanswered questions and swam in circles looking down for Joe. It may have been a few seconds or a few minutes later that he broke surface.

Decompression was one of those things we had heard about but never met. Nevertheless, I shouted to Joe and Peter to dive back to 10 meters to "decompress, just in case". So we hovered there at 10 meters, hanging onto coral heads, looking around or staring at one another for maybe 10 minutes until one of us ran out of air. We had a long swim back to the dinghy and clambered exhausted into it. The next moments I remember succinctly. One opened the cooler, drew out three SP brownies, opened them and passed one each to us.

"Cheers. Thanks for saving my life, Jay", said Peter.

"Yeah, me too", said Joe, the beer already muffling his words.

I continued my working dives, about three days each week, and our trio continued to explore diving areas around Port Moresby on weekends. We never spoke about that incident again.

On another occasion in those “innocent” diving years, we three dived on the half-exposed wartime wreck of the MacDhui in Port Moresby Harbour. The MacDhui's store rooms were lined with fluffy orange silt—nearly thirty years of rust. We entered one of the holds and immediately created a dense orange snowstorm so thick that we immediately lost contact with each other.

My two buddies were able to find and escape through the shell hole through which they had entered. However, I was carrying the Nikonos underwater camera on a strap around my neck and had a bag full of flash bulbs floating around me (this was before the days of electronic flashes; you had to insert the bulbs into the flash unit for each picture. The bulbs were very buoyant and would rocket to the surface if you fumbled). I was worried—panicking was probably closer—about becoming tangled on unseeable objects in or around the hold. Venturing upwards, daylight eventually shone through and I soon found myself at the surface inside the ship. My friends had surfaced outside the ship and were treated to the startling exhibition of a diver climbing up the rigging of the MacDhui in full scuba gear and plummeting down between them in a torrent of expletives and flashbulbs.

Strangely, we never encountered sharks when we were diving in the Moresby area. Often, there would be a great flurry of sand and silt ahead of us as we searched around the bed of the harbour looking for our research site. We preferred not to think about what caused it. On a few occasions, I joined the tuna-spotting flights along the coast from Moresby. Etched in my memory are the sights of dozens of big sharks at the surface, tearing into a school of large tuna that they had worked into a circle, right outside Port Moresby Harbour. Our small plane circled over the carnage, one wing almost vertically down so that if you fell out of the window or the engine stopped just then....the imagination did not have to run too wild. And then, of course, the memoirs of Margaret Mead, noted anthropologist, would come to mind. From her writing, I had the impression that sharks cruised the shores of the islands culling out children and the slower adults as they went.

Nevertheless, working trips to the outer islands were breathtaking in all ways—in the exotic, remote locations, never before dived; in the hazards of travel and transporting equipment; in the naive belief that we were immortal.

A Laboratory of One's Own

The research station, in Kanudi village, was a rudimentary L-shaped two-storey building facing south down Port Moresby Harbour, clad in glass louvres to catch the sea breeze. A dirt road that ran down the side of the harbour and separated the station from a thin mangrove stand over shallow mud, beyond which the water gradually deepened reaching nearly 30 meters in the middle of the harbour. To the north, the harbour narrowed and turned west, forming an inner harbour, Fairfax Harbour (Both named after Admiral Fairfax Moresby, father of the explorer who surveyed the area just a hundred years before, in 1873).

The research wing consisted of laboratories and offices in the back part of the "L". I was given a downstairs laboratory, i.e., a bare room, to do more or less whatever I wanted.

The scientific personnel were nearly all enthusiastic young professionals eager to make a success of their stint in the territory. Dress was very casual. Rubber slippers and loose shirts were considered formal, a far cry from the compulsory long-sleeved shirt and tie in Canberra.

There were 9 biologists at the station and one working in western Papua:

Win Filewood, who had been there many years and no longer qualified as being among the 'young professionals', was Chief Biologist. His main fisheries interest was in a long bin of preserved sharks along the outside wall the laboratories; however, it was rarely opened. He was best known as a bird expert, and was junior author on a book of the territory's birds. I must confess to have never consciously noticed a bird of any sort in Port Moresby, although a book published as recently as 1970 on The Birds of Port Moresby and District by Roy Mackay told me there were 364 bird species recorded in the area to 1968 and that "What is more surprising is that it is quite possible to observe a third of them in one week-end." With all the local bachelors hunting them down for feather trophies, I was a little sceptical of Roy's enthusiasm.

Joe Glucksman, dive buddy and freshwater biologist, was working on carp—he was hoping to culture a mixture of silver, grass and bighead carp in the highlands—and tilapia, all fish species that are anathema in Australia and, indeed alien to Papua New Guinea. However, tilapia had been introduced all around the Pacific from their native Africa and Middle East since the early 1950s, in those carefree development-at-full-steam days, when western researchers seemed to think the Pacific was a virgin field in which they could freely throw seeds of various plants, animals, and fish and watch what happened, with little thought or care about or responsibility for the possible future consequences.

Not until the 1980s was serious consideration given to these consequences. One obvious one was introducing diseases that could wipe out a whole population of the native fish or clams, etc. Even sending broodstock of a species already present in the host locality could not only bring disease but also change the genetic make up of the host population, which could as a result become less resilient to local conditions and die out.

As publisher of an influential, quarterly, tropical fisheries magazine (Naga, the ICLARM Quarterly) in the 1980s, I championed in an editorial a draft quarantine protocol for giant clams, which, like tilapia, carp, and for that matter, both edible and pearl oysters, were being moved around the Pacific like chess pieces. Giant clams were a test case.

For those used to doing what they liked in this regard, the prospect of quarantine and even a ban in some cases, was not taken well. Once, in Manila during one of the triennial Asian Fisheries Forums, a young researcher cum entrepreneur approached me and asked my name. When I told him, he burst out:

"Well, I'm going to sue you. You're ruining my business of exporting giant clams from my hatchery!"

Of course, he never did sue. And before long his aggressive behaviour landed him in trouble with island authorities and he quit the Pacific, leaving behind thousands of colourful orphans in the shallows of a sheltered bay where they soon became a tourist attraction.

Joe's fish were already living in the territory. He had the carps in holding tanks on the station. However, reports from later years indicate that neither grass nor silver carps were still present in the country.

Tilapia was one of at least 25 kinds of fish introduced into the territory at different times for farming. They arrived in the late 1950s, escaping, as fish are wont to do, into nearby rivers, where they thrived. In the Sepik, where they were accidentally released in the mid-1960s, tilapia multiplied rapidly and became the fish major harvest from the Sepik system within a decade. In part, this was because there were not many native fish species in the river and the numbers of those were comparatively few. Common carp became well established in the highlands. Both are now widely farmed in the country.

Overall, the tilapia harvests in the territory were making a dent in the imports of tinned mackerel from Japan, which were, with rice, one of, if not the major staple food of local residents. Rice was another imported staple; yet even now the territory has never grown more than an insignificant amount of rice.

Joe stands out among the staff. He was on the wild side. Always looking like he had just come from a party—albeit in tattered shorts—with a headband over his blondish shoulder-length hair, long drooping moustache and beard, an open colourful shirt and necklace with boar's tusk, and rubber slippers. His pale eyes always looked the worse for wear, which he ascribed to the many years of taking quinine. Hippie he was. Joe was much acclimatized to the local scene, had more than one local girlfriend and spoke at least some words in several dialects. I remember his often being in trouble with his girlfriends and sometimes could not come to work because he was in hiding.

As I mentioned. Joe and his Australian assistant were also my diving buddies on weekends. We borrowed the station's dinghy, filled it with scuba gear and beer and dived all along the coast adjacent to Port Moresby Harbour, where surely no one had ever dived before. Remarkable and adventurous days.

Between the pages of my suede bound note book, I found a torn piece of paper on which Joe had scribbled "Sorry I missed your farewell party last night. See you". I was surprised to have an 'aerogramme' from him four years later. In 1978, he wrote to me in Canberra from Florida. He had left Papua New Guinea "on short notice", due in part to a new disagreeable Chief Biologist and "on top of all this a Chimbu girlfriend (not the one you met) was trying to knife me and stole my car twice". Life was tough in Moresby.

Grant West, an Australian freshwater biologist, was working with Joe, investigating mainly the crustaceans, also with a view to their culture. The two were often in the highlands looking for native freshwater fish and shrimp, respectively, that might be useful for farming.

Bob Kearney, Tony Lewis, and Barney Smith—all ex University of Queensland—were the tuna team. Bob was a doctoral candidate while I was doing my masters there; Tony was a student in one of the classes for which I was a demonstrator. Theirs was not an enviable task. The aim was to find out the size and movement of tuna stocks in the territory; these were mainly skipjack tuna. Foreign, especially Japanese, fleets were harvesting vast quantities of these tuna but no one could or would say exactly how many fish they were taking or what effect this was having on the stocks.

The work involved tagging skipjack by the thousand to follow their migration paths and developing the tagging technique was outstanding in itself. To catch skipjack, the usual practice was to "chum' a tuna school, which meant steaming until the presence of birds indicated a school feeding on the surface, then throwing in live baitfish to keep the fish interested in remaining on the surface while fishing with lures. The baitfish had to be caught and kept alive on board. So the team had first to locate and net schools of baitfish. And not just any species would do. Careful handling was needed bringing them on board into the special wells inside the boat and the water kept moving; overcrowding had to be avoided; it would not do to arrive at a tuna school and find that the baitfish were already dead.

The tuna survived for less than a minute out of water, during which time they had to be flung aboard—sometimes between two fishers throwing the fish over their shoulder still attached to the barbless hook—tagged and thrown back in about 30 seconds.

As well the team had to gain access to catch data from the fishing fleets. They required the fleets to submit—and later had to analyse—detailed monthly forms on everything from bait used to reasons for not fishing on a particular day.

The results were well worth the Herculean effort. The skipjack were found to migrate vast distances across the Pacific and the management of the fisheries subsequently took on a more regional than national character. The tuna biologists all went on to continue the work for the then South Pacific Commission, laying the foundation for tuna management in the Pacific.

Pat Kailola, our captive Australian fish taxonomist, spent most of her time on station, identifying fish bought in by other biologists; very efficient, she always had an answer and a smile. Her systematic work put the territory's fish "on the map" and she later went on many expeditions identifying fish around the Pacific for regional and international organizations.

Fred Reynolds in Kanudi and Ray Moore in western Papua in the Fly River delta were studying the biology of barramundi resources around Papua. They found, mainly by tagging thousands of fish that, as in Australia, the adult barramundi mostly lived in freshwater and moved down river to coastal spawning grounds, travelling sometimes more than 600 kilometres, returning to much the same freshwater upriver areas. The young fish stay in coastal areas for about two years before travelling inland; some stay behind in the sea and not all the adult fish were found to migrate each year.

These were solid results vital for proper management of the barramundi fishery, which was small at the time but would no doubt grow as communications with and transport to Port Moresby improved. And the results were hard won. The field research in the Fly River by Ray Moore, for instance, must have been somewhat hazardous. While spearing fish—or lobsters, on which he was also working—in the turbid waters of the delta, he would sometimes be bumped by sharks attempting to take his specimen; he related stories of having to push these sharks away like naughty children. It made my blood run cold, although he was always lighthearted about it. Monstrous saw sharks, up to 6 meters long, with their evil toothed snouts were occasionally netted hundreds of miles upstream in the Fly, in freshwater.

Reynolds and Moore also investigated barramundi farming potential. It was more than a quarter of a century before that work bore fruit, in a hatchery and grow-out farm in Madang Province and some farming in cages in the Fly River.

The Papua New Guinean support staff were in general a happy group, likely to break into strange songs that evoked the mysteries of their tribal lives, which we called primitive, although they were much more closely in tune with the land and sea than we expatriates could ever hope to be. They were also a disparate group, some almost shiny black in skin colour from New Guinea tribes that occupied the northern half of the island and outer islands; while others were more lightly tanned from the southern or Papuan side. Conflicts were not common but were most likely to occur on pay day.

There was a large Chinese store—just about all the stores of any stature were called Chinese stores and indeed they were virtually all owned by Chinese—on a corner of the road by the research station at Kanudi. On pay days, it was a favourite haunt of the local station staff. Here would wait some of their wontoks, friends from the same village and/or tribe, for handouts. Wontoks were the extended family; one person working for the government might be supporting dozens of wontoks who had travelled from their often remote villages to taste “city” life. They created a hazard for both local and expat residents, being unemployed, illiterate, and very liable to fight among themselves; and they might attempt to rob residents.

At the Kanudi Chinese store, much of the pay day cash of the station staff went straight into the till, for cases of SP greenies, which, like brownies, were small bottles of South Pacific brand beer. These were drunk immediately by staff and their wontoks outside the store. After one or two beers some would get either excessively happy or excessively belligerent. One of our support staff was hacked to death during one of these "happy hours".

My two research assistants, Vitus and Hippo were both Papuan graduates from a local college. They were partially interested in the work but were not trained or inclined to see beyond the immediate tasks. The water temperature measurements they took, for instance, showed a gentle rise and fall over the months, but occasionally the log book would include a reading 5 or 6 degrees higher, an impossible reading, without comment.

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My own research at our station was not going to be easy. Field work was complicated by the remoteness of everything outside Port Moresby, which itself was hardly cosmopolitan. Two months into my work, I found all the research gear that I needed was away on the two 35-foot research "trawlers", Rossel and Tagula, but they had their own troubles. I wrote:

> "The Rossel had to cut short a barramundi trip the other day when one of the crew developed appendicitis. Also the Tagula, out on its first few days of an expedition, blew the gearbox and will require a major overhaul."

And a week or so later:

> "Funds are abundant here. There is absolutely no difficulty in obtaining money for whatever equipment I need…The only problem, and it is a big one for goods that need to be imported, is the delay in actually getting the goods. Indents take time, from one month to three years in one case I know

> of here. Items from Australia take the least time so I endeavour to obtain supplies there."

My laboratory gradually became a working room. I wanted to culture the local oysters and pearl oysters if possible, from eggs to get an idea of this method of producing stocks and to determine the temperature and salinity conditions the oysters favoured for their reproduction. That is, I needed to know what turned them on! The room began to fill with small and large aquaria and fairly unsophisticated electronic apparatus.

In the early days, I sent some unappealing descriptions of working conditions to Albert and company in Canberra now and then when I was vexed, such as:

> "I'm typing on a stool with the typewriter on a freezer with a 16 inch fan beside me; I am sweating. One assistant Vitus, a nervous chap with huge lips, is washing a tube through which I will shortly filter seawater via charcoal and glass wool. Hippo, the other, is sitting in the gear shed with apparent incipient malaria."

By June, I was clearly still enthusiastic about the work. I wrote:

> "My work is exciting, involving everything from helicopters to submersibles, rather different to my seat [in Canberra], where the only excitement was the photocopying girl disappearing down the corridor or a new leaf on my 'executive' rubber plant'."

Actually, the submersible remained land bound. It was wooden contraption, 'brain' child of our English boat master, Ernie, painted bright yellow and looking anything but efficient underwater. It was meant to be towed and I thought towing it out to sea and letting go the tow rope would have been a good idea. I can't remember the photocopying girl in question. The rubber plant was the sole touch of green in the near monochrome grey environment in the Fisheries Division in Canberra.

However, the helicopter work was really exciting. I used one of those small bubble machines that look like dragonflies held together with matchsticks, to hover over the sea while I lowered a device to take water samples. This made the pilot extremely twitchy. “Hurry up” he would always bark over the sound of the thrashing blades as I hung out the side—there were no windows or door—retrieving the sampler.

On one of these occasions I asked him: “What happens if the engine fails? Do these things float?”

“Yeah”, he replied, “like a streamlined manhole cover”.

Meeting the Oysters

With a mandate to examine the prospects for oyster and pearl oyster farming in the territory, I began by looking at what had been done in the past. I found a few mouldy Manila folders with pages of pink or green carbon copies of reports to the Chief Biologist hanging out of them in an old rusting filing cabinet. It wasn't much; but it was all there was. There were a lot of measurements and other data that for all the effort were not encouraging. I sent, much later, the "original" pinks and greens to the SeaLife online database for safekeeping, to become a digital record. They were mostly about edible oysters. The idea of pearl oyster culture had arrived only a few years before my arrival with the establishment of the pearl farm in Port Moresby Harbour.

Reticent rock oysters

The earliest recorded oyster farming experiments were by biologist William Reed in the Central District west of Port Moresby and in Port Moresby harbour itself during 1956. The oyster species were not identified but they grew fast, remained lean and seemed to die within a year. There were no obvious conclusions or pointers for future researchers. In 1960, another marine biologist, Martin Stuart-Fox, carried out farming trials in Milne Bay, at the eastern end of the mainland. Most of the oysters were killed by gastropod shellfish borers, which were small snails that sucked out the oysters' tissues; others were buried under silt.

During the next year, Martin found good settlement and growth of oysters in other locations in Milne Bay, despite a heavy death toll from the borers and overgrowth by fouling organisms, such as sea squirts and barnacles.

After six months, the experiments suddenly ended; there were no more reports. It took me more than 30 years and an internet search to find out why: Martin left the territory, the oysters, and the biological world to reinvent himself. He wrote to me that he "headed off to Southeast Asia, became a war correspondent, and later returned to the University of Queensland, where I eventually became professor of history, publishing widely on Southeast Asian history, politics and religion".

Martin added: "By the way, the other fisheries biologist who arrived in PNG at the same time as me, and with whom I shared a donga [house], was Rod Bucknell (he was freshwater, I was marine), who had an equally colourful career. After PNG he became a Buddhist monk in Thailand, learned Pali and Chinese, and ended up as Associate Professor at [the University of Queensland] teaching Chinese and Buddhist studies. He and I collaborated many years later on a book called *The Twilight Language*".

The call to Asia was easy to understand among expatriates. The early 1960s were turbulent years in Southeast Asia. The Vietnam War, which encompassed Cambodia and Laos as well, had finally made Australia acutely aware of the great Asian landmass that lay between it and the "known world". My old history book, published in the 1950s, had a map showing the position of major places in the world in relation to Australia's capital, Canberra. In the entire hemisphere around Canberra, the only places shown were Peiping (Beijing), Djakarta, Tokyo and the South Pole. Asia simply represented in Australian minds—colored by the White Australia Policy—the "yellow peril" of communism that could creep south and swallow Australia (and Papua New Guinea would be an appetizer on the way). Or would there be the resurgence of Japanese imperialism?

My own future was to be in Southeast Asia too, in the then wild west of the Philippines.

Meanwhile, in Papua New Guinea, the early oyster farming experimenters did not hazard a guess as to what oyster species were on hand and even today, the classification of oysters around the Pacific remains confusing.

Investigating the nearby oyster resources was my next step. By the end of my first week at the station, I wrote in a letter south:

> "Right now I have two assistants, local, collecting oysters off the wreck of the MacDhui, a merchant ship sunk during World war II about two hundred yards offshore. Yesterday the three of us made a survey of edible oyster resources around the harbour. Amazing to see locals on outrigger canoes, the men diving with spears, women and children on board the tiny craft and perhaps cooking the fish with a fire on the canoe; then to look past them to the new big buildings of Moresby, and to recall that on Saturday these same people were voting for control of the territory in one fashion or another.
>
> One of the assistants is Hippo, tall thin from Central District, whose father is teaching him the magic words of the puri-puri man. He claims he was bitten by a deadly Papuan black snake the other day but the words saved him. I saw the punctures. He also says that some words can cure broken backs and skulls, other words can break up marriages, seduce women and so on. The other assistant is Albert who speaks only Pidgin so we talk about 'dispela bilong liklik golip', that is, young goldlip pearl oysters."

Around Port Moresby, I found three "varieties" of rock oysters that could be distinguished consistently: the large mangrove (*Crassostrea echinata*), and much smaller—most being too small to consider eating—spiny oyster, which was possibly a smaller variety of the mangrove oyster, and even smaller milky oysters (*Crassostrea amasa*), respectively. These are old Latin names but I have little faith in the more recent attempts to classify tropical oysters.

We needed broodstock or resident populations of edible and pearl oysters if any kind of farming were to eventuate. Soon I was using one of the research trawlers to survey the area around Port Moresby. I had a team of eight local divers who would fan out from the boat at various sites around the harbour and along the coast inside the outer barrier reef, snorkelling to collect samples of the different kinds of oysters and pearl oysters.

These surveys showed us that the three types of edible rock oysters had different habitat preferences and that, among the wild stocks, only the mangrove oyster was worth eating, that is became fat with ripening gonads. Alas, unlike the other two types, mangrove oysters were few and far between.

Traditionally, oyster farming is done by setting out collectors on which the baby oysters, or spat, settle. As the oysters grow or become crowded, they may be chipped apart and transferred to trays.

Port Moresby Harbour was still reasonably pristine and a good place to investigate both edible and pearl oyster farming prospects. I set up a sampling program in the harbour: water temperature and salinity were measured daily and racks of cement fibre ("fibro") strips like large, open Venetian blinds set out in the intertidal zone or hanging lower in the water column from a buoy to learn, on a weekly basis, what organisms would settle out of the plankton, the tiny animals and plants that drift in the water currents or have limited swimming power to avoid them, onto their upper and lower surface and how fast they would grow. Later, racks of fibro and hanging coir ropes were set up at several more sites and this was extended to more sophisticated fibreglass cones suspended at different depths and sites in the harbour to attract baby pearl oysters.

My notes were a maze of brief commentaries, rarely complete sentences; some even written vertically down the page where rows of lengths and widths of oysters took most of the space. Most of the descriptions were short and, from the present distance of several thousand kilometres and some 40 years, frustratingly obscure.

Many pages were filled with columns of temperature and salinity readings from Port Moresby's near surface water, carried out by my assistants who made almost daily trips from the station to our boatshed, the "marine base", near the city. Salinities had to be determined by titration, dropping a silver nitrate solution from a measuring cylinder, a burette, into the sample until the indicator colour disappeared. That gave a value of the amount of chloride in the water, which was then multiplied by a factor to give the salinity in parts per thousand. The silver nitrate concentration had to be checked each time against standard seawater—a small quantity of which I received through an indent, an overseas order, and which became more like gold as it was gradually consumed, even though I also made secondary standard solutions to stretch its longevity. Later, an electronic probe for both salinity and temperature (S-T meter) became available, though it still needed checking against the standard now and then. All the effort was summarized in print in a few short columns that showed the harbour surface water to range from 24.9 to 30.4 degrees centigrade, and salinity from 32.9 to 38.0 (rather high) parts per thousand.

There were several notes about the collectors: “racks destroyed; replaced on…”, and sometimes the collectors were simply covered in young barnacles and/or a small pearl oyster species that had my heart racing at first, in the thought that it might be goldlip pearl oyster spat. Sea squirts, which resembled little pithed olives and released a fountain of water when pressed, were another nuisance on the collectors, often leaving no space for any young oysters looking for a foothold.

Despite the various setbacks and disappointments with the collectors, a few general observations emerged from the two years of effort: the milky oyster spat were only found on collectors in the outer harbour where regular monitoring was not easy; their size and preference for exposed conditions would make them less favourable candidates for farming. Collectors that were set out in the central harbour fairly regularly over the two years received several spatfalls of the small spiny oysters—a major spatfall during March–May 1972, and minor spatfalls from November 1972 to April 1973. Outside these periods, there was little, but some, settlement. The spat, after a few months, grew to the size and shape of small coins, rounded and quite flat.

For mangrove oysters, my notes show that I wrote to the vice chancellor of the University of Papua New Guinea for permission to set up a small oyster growing experiment at their research station on Motupore Island in Bootless Bay, adjacent to the Port Moresby Harbour. The letter must have met with approval because my assistants set out cement bricks where we had seen the adult oysters growing in moderate profusion. However, during a whole year, no settlement was recorded. Empty shells held in netting bags, another oft-used ploy to attract baby oysters, were also set out in the area, but these also remained empty of spat.

To catch plankton, you need a net. Not just any net, but one designed to catch the particular type of plankton you want. There is zooplankton, the animal plankton, made up primarily of countless types of tiny shrimp-like animals, worms, jellyfish, and the larval stages of fish, molluscs, and other crustaceans. And there is phytoplankton, the plant plankton, made of again countless types of algae, the more common being single cells. The phytoplankton is far smaller than zooplankton and so needs a very fine meshed net to catch the bulk of algal types. You had to buy the netting from a scientific supply store overseas; not even the Chinese stores stocked plankton netting in the territory. I was interested in the phytoplankton, as it was the food of oysters and pearl oysters. Thus, I chose, from an esoteric scientific catalogue lying around the Kanudi station, a net with a mesh size of 48 thousandths of a millimetre, that is, 48 microns. This is in the range of small phytoplankton and could also capture mollusc larvae, which are slow moving; most zooplankton can leap out of the way of such a net, aided by its “bow wave” during towing. The choice was fortuitous because not long after, the question of red tides of toxic algae was to arise and I had the only net in the territory that could catch them in bulk.

When the netting eventually arrived and was made up into a tall conical shape with a removable collecting bottle at the cone’s tip, I or my assistants made near-surface phytoplankton hauls in Port Moresby Harbour every two weeks. Disappointingly, we caught very few oyster larvae, certainly not enough to detect any seasonal pattern. In science, a negative result is as good as a positive one, though it means one's ideas, hypotheses, may have to change. In this case, the missing larvae remained something of an enigma.

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Despite the occasional or rare nature of spatfall in the three oyster varieties around Port Moresby, I found that oysters had active sperm and viable eggs all year round, so there was plenty of opportunity to study their reproduction and development of the young oysters.

Working out the spawning seasons was a tedious investigation though. Each week, several dozen specimens of the three oyster varieties from the harbour were "sacrificed", the technical euphemism for "killed". We smeared small amounts of their gonad tissue onto microscope slides and observed the state of the reproductive cells under a high-power microscope. It was fairly easy to distinguish their sex and whether they were ripe, or about to spawn; spending, in the process shedding or spawning or had recently shed eggs or sperm; or spent, in which the gonads were immature or empty—"flaccid" is the term used (the gonads then look like a deflated hot air balloon, but you wouldn't call it *flaccid*, would you?)

Interestingly, the ratio of male to female oysters varied considerably from month to month without any obvious pattern. For the milky oysters, ripe males and females were found in the "winter" months (June and July). The rest of the time, most of them were in a state of spawning. Spiny oysters were fairly ripe over a longer period (June to November), but most were apparently shedding eggs or sperm throughout the year. Mangrove oysters were also apparently in a constant state of spawning.

Ripeness is a measure of "condition" or vice versa. Oysters are only worth harvesting and eating when they are fully ripe, that is, when their gonads are full. To quantify this, we measured the condition of the oysters from time to time in terms of the volume of tissues as a percentage of shell space (whole volume minus volume of shells). This was simply done by measuring the water displaced by the intact oyster, the drained tissues, and that of the two shells. Spiny rock oysters never attained "good" condition (say over 90% full) although close to ripe in the latter part of the year.

Mangrove oysters, surprisingly, exhibited good condition over several months, from October to March and in July, despite their continuous spending. Broadly, these were months outside the short rainy season. However, in October and November their condition was relatively poor. And usually, even when in good condition, the gonads had a slightly lined appearance (like half-filled hot air balloons), unlike the smooth white texture of, say, ripe Sydney rock oysters. As the mangrove oysters were the only oysters large enough to consider farming in Papua New Guinea, their continuous spawning behaviour and unpredictable "seasonal" good condition cast a serious shadow over oyster farming prospects.

For a few months, some of my spat collectors sported dentures! An expatriate dentist at the local Dental College, Glen Wolter, was experimenting with the idea of using natural adhesives to hold dentures together. It is well known that barnacles glue themselves to rocks and the sides of ships tighter than a widow's wallet. Glen wanted to see how the glue worked on dentures. Could barnacle glue be synthesized and used as a denture adhesive? Barnacles certainly liked our spat collectors; before long I was able to provide him with some bizarre-looking barnacle-encrusted teeth and he went away happy. Much later, after I left the country, I wrote to find out their fate, only to learn from Glen that

> "…since your departure, the dental college saw the departure of two of our staff and yours truly is now the Principal of this auspicious outfit….Our masters give us no time or money for research. We are just mechanical organitrons!"

By July 1972, I had farming experiments running on both pearl and edible oysters. Some of the strain and excitement showed through in a letter I wrote to Albert on 20 July 1972:

> "Pretty busy at the moment…I'm preparing for a trip to the Trobriand Islands next week, while at the same time trying to maintain an oyster program here. Diving and plankton hauling today; started [an algal] culture yesterday; field trip the day before, and flying along the coast on an aerial survey tomorrow; collecting some frozen oysters from Lae tonight; photographing a rare fish from the harbour now…"

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Considerable energy was devoted to trying to grow oysters in the laboratory. The idea was to find out about the early stages, never before described, what kind of materials they might prefer to settle on, and how fast they would grow. The work was done in parallel with the field sampling and spat collection.

From the beginning, these spawning experiments fascinated me. Seeing under the microscope the big round eggs and the sperm swimming around them, it was as if I were creating life. In the laboratory of the Zoology Department of the University of Queensland, I had often shown students this beginning of life in sea urchins; they and I watched in awe the sperm forming a dense ring around a sea urchin egg, wriggling rapidly against it, desperately trying to enter. Then one of the thousands of sperm, just one, penetrated the egg. The deed was done and all the other sperm immediately drifted away.

That was life begun on a microscope slide; afterwards, the slide was taken away and washed, the process aborted. Now in my laboratory in Papua New Guinea, I was attempting to spawn and grow oysters; the oysters produced thousands of eggs and countless million sperm. I imaged a vast crop of siblings that I would eventually place in a farm in the harbour.

The three rock oyster varieties had different spawning preferences in terms of salinity and temperature. It was not difficult to discover these. There were usually enough ripe individuals in the wild to collect samples for spawning experiments in the laboratory. They were opened and tiny amounts of their gonads inspected under a high-power microscope. The presence of large eggs or moving sperm indicated useable material. However, I needed two unavailable items to complete the equipment needed for the task. As a result the research had to wait several months.

The catalogue at the station that I mentioned was big, thick, and well-thumbed. It contained endless lists of scientific equipment. It was like a department store catalogue but the pictures and descriptions were of another world: chemicals with improbable names like a secret cipher; glassware; and strange machines, large and small—some reminiscent of a horror movie—for any physical, chemical or biological research imaginable. Yet, it seemed *un*imaginable that such apparatus could ever find its way to a tiny laboratory in a small harbour in a remote tropical colony. My needs were relatively simple—a constant temperature bath and fine-mesh netting for sieves to wash the eggs. Indents were duly made and dispatched; although I felt it was like writing to Father Christmas.

I had plenty of other work to keep me busy and had almost forgotten the indents when, after three months, a small parcel arrived at the station: it was the electronic device that would keep the water temperature steady within a tenth of a degree. Shortly after, the package of netting was also delivered and I was nearly ready to begin the spawning trials. Nearly, because, as with the phytoplankton sampling in the harbour, the netting was not simply of the kind to keep out mosquitoes. Each length was of stated, accurate, mesh size to the nearest few microns. The eggs were up to 60 microns wide on average so I used 80, 60, and 40 micron mesh and made sieves by placing the material over the ends of connector pieces for six-inch plastic pipes. The sieves sat one inside the next. The egg water was gently poured in; most of the debris stayed on the top sieve and most of the eggs stayed on the middle sieve, where I could wash them with additional filtered seawater. It was a simple but efficient apparatus and it suited our needs.

All we had to do was add a little sperm to the washed eggs waiting in their seawater baths. Yet it was never less than thrilling to watch the progress of life from its very beginning. Were it taking place in some sterile, well-equipped white-walled room in a cosmopolitan university, it may have had less impact on me. As it was, the surroundings lent an almost arcane atmosphere to the experiments.

Small samples withdrawn from the dishes every 5 minutes and viewed under the high-power microscope soon showed the eggs dividing into two. In my warm laboratory, this miracle of life took place in about one hour; in another 20 minutes one of the cells had divided again, and there were four cells by 90 minutes, eight in two hours. The thousands of eggs in the dishes were all doing the same thing at much the same time, wonderful.

Thereafter, the dividing cells began to resemble microscopic blackberries or raspberries, ovoid bumpy creatures that soon began to move, to swim, under their own power, with tiny hairs beating together—with a myriad Lilliputian oarsmen hidden inside; it felt almost miraculous to my gigantic eye peering down and seeing them one or two hundred times their actual size passing across the illuminated slide, brought to life by an act of mine. These little swimmers were the trochophores and they were looking for food. And after several more hours, they grew shells and looked like the capital letter 'D'; so they are called D-larvae. And that was as far as they ever reached in the laboratory.

I did these experiments in a wide variety of temperatures and salinities. Fertilization could be seen in samples at most combinations of temperature and salinity but development of the larvae was fastest in only a few and in the slowest combinations the larvae became deformed.

At first I was at a loss to interpret the results. If the larvae grew equally fast in several different salinity and temperature combinations, which, if any, should be called the "best"? When I plotted the results in graphical form, the answer became clear. By drawing lines between combinations that gave about the same larval development speed, a series of concentric ellipses was formed and the centre of these was the single fastest combination. It is a slight leap of faith to say fastest is best, but since the slowest combinations led to deformed larvae, there was certainly much to be said in favour of speed.

The results were partly what I expected; they confirmed my earlier conclusions based on seeing where they lived in nature. The milky oysters showed best reproductive performance in cooler, more saline water and this fitted nicely with their habitat preference for more exposed areas of the outer harbour. The mangrove and spiny oysters preferred higher temperature and lower salinity, which is characteristic of bays and harbours affected by freshwater inflow, and these were also the main mangrove habitats. More interesting was that these two varieties had almost the same temperature and salinity preferences. Perhaps they were after all the same species.

The spawning experiments had their end point at the D-larva stage because they needed food and starvation would affect them toward the end of that stage. The 10-year old mollusc culture bible on hand and the research results in more recent papers recommended a variety of algal feeds for oyster larvae. But all were intended for temperate, not tropical, oyster farming conditions. The food algae had to be kept in the laboratory as "monocultures", that is containing only one species of algae; if there was a mixture of algal species, it would be difficult to learn which ones were deemed edible by the oysters. Also one species would inevitably outcompete the others, which would soon die out.

I sent off to my friend from the marine biochemistry unit at the CSIRO, Shirley Jeffrey, for sterile monocultures of the kinds of algae that the scientific literature said would be eaten by baby oysters of other species. Blithely, I asked the local Department of Agriculture, Stock and Fisheries for permission "to import four small cultures of the following marine algae, which have worldwide distribution: *Monochrysis, Isochrysis, Dunaliella*, and *Chlorella*". I received a copy of a letter to the Assistant Director dated 4 days later from the Chief Plant Pathologist Dorothy Shaw, who noted some caveats about these microalgae, and asked for the species names. It was a mild rebuke, but it was heartening to know that an import control system was in place.

The paperwork was duly done and the cultures soon arrived by airfreight—and were a great responsibility. I had to maintain some of them in the same culture, from which I would draw samples to grow in large tanks, fed with certain chemicals in a certain proportion to encourage their growth so that I would have enough food to keep the oyster larvae alive. For this, I ordered over the previous months an ultra-violet light water sterilizer from Germany, and an electronic salinity and temperature meter from England. Supplies of chemicals came from Sydney.

All the equipment was in place when the cultures arrived. We made our own fibreglass covered wooden containers to store the treated seawater that would flow through the tanks of baby oysters.

Ripe oysters were nearly always on hand and my laboratory notes always began encouragingly "All cultures flourishing; close to 100% fertilization", etc. Sometimes, sperm could be activated by addition of traces of ammonium hydroxide, something often used as a household cleaner; it's a technique I picked up from the pearl culture literature.

Despite providing what the literature said were the necessary conditions to grow algae using various culture media—broths of chemicals (grandly called Loosanoff's nutrients A and B) that substituted for nutrients in the sea—two of the starter cultures died out within three days, presumably due to temperature stress; alas, they (*Isochrysis* and *Monochrysis*) were the more favoured, more acceptable oyster larvae foods, according to the literature; but, of course, the literature was based on experiments in somewhat cooler places like Chesapeake Bay in the northern USA. The remaining algae (*Dunaliella* and *Chlorella* species) did prosper for some time in laboratory aquaria but the oyster larvae would have none of them.

It was heartbreaking to see the baby oysters ignoring the food. I tried a wide range of algae concentrations without success. Some of the algal cells could swim faster than the oysters (!). Thanks to Alan Peterson at the “Base Medical”, I was able to get hold of small amounts of various antibiotics, some of which were recommended for oyster hatcheries to prevent infections that might weaken the larvae. Tetracycline and penicillin didn’t help but streptomycin increased survival to the D-stage, in some cases by a factor of 10.

Was the shape of the containers another factor? Larvae were settling on the flat bottom of dishes and bottles. So I placed different combinations of fertilized eggs and algae in large inverted cones of the sort used to mark road lanes, with aeration coming from beneath. But only the algae increased in concentration. The oyster larvae that were supposed to eat them were not interested.

We tried transferring them to outdoor tanks, along with suitable concentrations of algae. After several trials, all we had for our troubles after a few weeks was a handful of spat.

By then I had reached the end of my first year in the territory and I decided I was juggling too many research balls. I was not able to concentrate on any one of them.

All the evidence showed that edible oyster research had to be dropped. Farming the local oysters in Port Moresby would be expensive, as natural spatfall had proven unreliable and a hatchery operation was not practical. A farming enterprise would have to look toward exports because local demand would be extremely small. If farming was not possible around Port Moresby, it was not going to be feasible elsewhere in the territory in the near term—the cost of getting oysters from outer islands and then sending them on to overseas destinations would be prohibitive. Additionally, with so many other tiny animals in the sea constantly wanting to settle out of the plankton onto whatever surface was available—including settling onto oysters—the young oysters would have to be cleaned every month, another large expense.

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However, I did continue to investigate the available plankton in Port Moresby Harbour on a fortnightly basis to learn their seasonality, whether bivalve mollusc larvae like those of oysters and pearl oysters might be found, and what the plant plankton was available as food for them. Soon, I would be using the net to look for more deadly organisms, of much the same size as oyster larvae, in the harbour's water.

The results of the regular plankton hauls could be compared because much the same amount of water was filtered by the plankton net on each occasion. From a fixed buoy, the net was let out behind the outboard motor boat and kept about a metre below the surface for five minutes as we headed for a certain landmark with the engine at almost idling speed, just fast enough to keep the net from sinking. I could find out which organisms were dominant and when, that is, an idea of the annual succession of the plankton.

I hated the thought of phytoplankton analysis. The microscopic size of all the species meant staring down a high-power microscope for hours, with a strong light pointing up into my eyes from below the stage on which the slide of plankton sat; bad enough on the eyes but compounded by the nauseating smell of formalin from the preserved samples. I was almost allergic to the formalin as a result of examining bins of formalin-pickled fish for identification and sometimes for dissection to see what they ate, during my master's degree research at the University of Queensland.

One particular moment locked the association of nausea, distress and formalin in my brain forever. I was working into the early hours of the morning at my desk in the university's Zoology Department, my eyes by then literally in tears from the effect of formalin vapours from the specimens I was examining. My stomach was heaving from the smell. Save the fluorescent light high above me the whole department was in darkness. Old darkly stained partitions lent a gloomy and disturbing atmosphere to the room, and they creaked occasionally, heartstoppingly, in the wind that easily penetrated the drafty building.

Then, from nowhere, a sudden explosion rocked the room, rattled the windows and partitions and echoed along the corridors. It was so loud it hurt my ears. At the same time, the light went out and I was in complete darkness, feeling small objects falling on my head and shoulders. I brushed them off and felt my way shakily to the door. In the corridor I found a light switch. It worked, a very welcome light filled the hallway and I saw my hand was bleeding. I stood there for what seemed a long time wondering what had happened until a night watchman came striding down the corridor. Together we went back into my room, his flashlight roaming over the walls and ceiling and floor. The floor began to crackle underfoot—broken glass. There was the cause. Above my head, a fluorescent light had exploded, showering me in fragments of fine glass. I had cut my hand on them brushing some from my hair or clothes. Yes, I dislike and am always wary of fluorescent lights too.

Yet I spent countless hours, day and night, in my laboratory at Kanudi, identifying and counting dozens and dozens of plankton types under that microscope, with that same formalin smell permeating the room. The reason was that although, or because, I was no plankton taxonomist, I was simply amazed and in awe of the diversity on a single slide; even more so when I had live organisms moving around there; such a variety of locomotion methods and speeds, and shapes and sizes from the grotesque to the unquestionably beautiful, and from utter simplicity to baffling complexity; armour of spines and spikes and shields, propellers made of whips and oars made of hairs; and it was all there under the microscope in dimensions measured in microns.

My rough estimates on the amount of plankton in the water were breathtaking to me, but of course, normal to a plankton specialist, There were tens of thousands of the more dominant ones per litre; multiply that and the numbers of the less dense organisms, of which I had only a small subset dictated by the net dimensions, and the totals were probably in the hundreds of thousands per litre of seawater. Later I learned that even smaller creatures were much more plentiful: bacteria are normally present by the millions per litre of seawater.

I managed to overcome my repugnance of formalin and took great pleasure in attempting to identify the plankton from various books on hand; positive identifications in turn helped me to classify other similar creatures and decide on how to group them to make sense of them all. I made a list of some 40 major types of plankton in my samples, added columns for quantities and comments and had the form roneoed—a method of duplicating using ink and placing a stencil of the original page around a drum; a technology that was already a hundred years old then and soon to be replaced by the 'Xerox' machine—by the dozen. The filled-in pages are long gone. What remains is a chart, later published, of the relative abundance over time of the main plankton types that I found.

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The results of the rock oyster spawning trials were not published until 2008. I made a report in 1973 while still in Papua New Guinea but it was rejected by the scientific journal publishers because I was not able to reference enough previous works on spawning of related species. It was most annoying, to say the least.

Why didn't I make reference to enough previous publications about oyster spawning? Remember the colony was still remote from mainstream amenities. Lack of pertinent literature was a recurrent problem in our laboratories. If we were aware of a certain published paper, we could write to the author for a reprint. There were special Reprint Request forms for this but they were very terse and sounded more like demands than requests. If it was a report or book chapter, we generally had to fill in a different, longer form and pass it to the small central library that served several government departments. It was generally quite efficient at retrieving papers and reports, but they might arrive several months after the request was made and their purpose all but forgotten, especially if, after the long wait, the contents belied the title, something not uncommon.

Developing-country mails are still slow and unpredictable but in those days there was no computer back up or internet short cut.

International telephone calls were discouraged, both by cost and available technology.

We were writing reprint and other literature requests on a daily basis so it was difficult to say what the success rate of paper “capture” actually was, short of starting our own recording systems; writing the requests and filling in the forms was more than enough of a headache at the time.

Added to all that, the photocopies themselves were primitive; if made on light-sensitive paper, they might be already unreadable by the time they arrived. Ink-based copies were often over-exposed and some words partially blackened out. A reprint was a paper reproduced in offset form by the publishing journal and given or sold to the author for his or her distribution. A good reprint was a valuable resource.

Finally, to request meant knowing about a given paper, chapter or report. Literature on tropical biology often lay outside the mainstream or “primary” journal literature, and along with papers and reports on a wide variety of development subjects, was known as grey literature. Grey could be equated with “hard to get”. So, while a weekly periodical that gave the contents of leading journals was available, it reflected almost entirely the scientific progress in temperate areas. And copies of the contents periodical tended to accumulate on the desks of scientists who were out in the field. A pile of these periodicals would arrive on the next reader’s desk, which he or she had no time to plough through. The pile would grow higher as more arrived and finally the whole bunch would be passed in despair, without being read, to the next person.

I was to discover later how important was the grey literature, which is still ignored by most western journals and many western scientists as being not “primary” (one pertinent implication being that a scientist—and this still is the case even in developing countries—does not get credits toward promotion for articles published in the grey literature, while for publications in the primary literature, there is a scale of credits depending on the standing of the journal).

While working for the International Center for Living Aquatic Resources Management in Manila, I had our library embark on a large project to find out how our published material, a mix of primary literature and “grey” reports, was being used, or cited. Over the course of a year, we found that both kinds of our publications were being cited more in the grey than the primary literature by a factor of 10. Thus, our output was not only being used in academic literature, it was being applied, and to a much greater extent, in the grey or ‘development’ literature where it was most useful. We were reaching our target audience.

Denis George, mentioned earlier, was a pearl farming pioneer in Samarai, Papua New Guinea for many years. He wrote in 1993 from his retirement in Cairns, Australia, to the Pearl Oyster Information Bulletin of the then South Pacific Commission (SPC) “I am pleased with the initiative to preserve the 'grey' literature, as I have plenty of that. As my days are coming to an end, I would like to see better utilisation of my accumulated files/library/experiences and I feel they would be more effective if sold to someone who will appreciate them. Do you know anyone who could be interested?” I felt a lump in my throat when I read this. Denis was dying of cancer; I was glad I had been able to contribute to his library and help with the village cooperatives he tried to develop to grow pearls. My first contact with Denis became an interesting adventure, described later.

Perplexing Pearl Oysters

Just what and where were these mysterious oysters that produce pearls of great price? I was eager to see them at first hand, but I wanted to be able to look at them with some pre-knowledge and not be embarrassed by not knowing which end of the oyster was up. Pliny in first century AD in Rome wrote of them with the authoritative language of an expert but he obviously had never seen one. He did know that pearl fishing was hazardous because of the high value placed on pearls: “that which is obtained with the utmost hazard is most regarded by the mind of man. The principal and summit of all these things, as regards the price, are pearls," and "they are sought among "many and terrible beasts."

Pearl oysters, he believed, moved in a flock like bees with a chief, the largest and oldest oyster, which was guarding them from danger. The pearl fisher must try to catch this one, after which the others will scatter and are easily caught in nets. But this story dates back unchanged to the Greek philosopher Theophrastus in the 4th century BC and may already have been accepted lore at that time.

One kind of pearl oyster produces pearls that are soft but harden in the hand, Pliny tells us; but we must beware of this shell, for when it senses the hand of the fisher it can close quickly, cutting off the hand with its sharp edge; besides it is often accompanied by sharks.

It gives pause for thought that such stories were believed over many centuries. There is some basis for assuming that pearl oysters swim, however; the not so distantly related scallop family includes species that do leap up from the sea bed and swim away from predators in a jerky fashion. Yet, the marine pearl oysters that are the subjects of these stories attach themselves semi-permanently to a firm substrate by a small beard-like growth called a byssus, similar to that of mussels. And it is not impossible to cut one's hand on the sharp edges of the outer horny layer of their shells—if drawn across the hand like a knife.

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The pearl fisheries of antiquity that provided the large and lustrous pearls most sought after were nearly all based on one kind of pearl oyster. We know it now as the blacklip pearl oyster (*Pinctada margaritifera*). The closest and best pearl grounds were around the Red Sea and Persian Gulf. The other major fisheries were around the southern coasts of India and Sri Lanka.

My interest was the South Pacific. Were blacklips present in Papua New Guinea and if so are they abundant anywhere? They are recorded to be widespread across the tropical western Pacific and Indian oceans. Generally living on reefs from the intertidal zone down to about 40 meters, they attach themselves facing upward and with their dark shells are difficult to spot.

I read that blacklips were plentiful in the Polynesian islands. In Tahiti, European contact in the 1800s triggered a lucrative trade in blacklip pearl shell until the beginning of the twentieth century when quotas had to be imposed and some areas closed because their numbers were plummeting.

Blacklip pearl oyster farms to grow black pearls in Tahiti began in the 1960s. Spat collection was very successful too and has provided stocks for farming rather than relying on natural settlement, which could easily be depleted again as in the past, given the new enthusiasm to grow pearls there. I remember marvelling at the low price of these wonderful objects from Tahiti. Surely they were fake pearls to be so cheap. Once they started to become accepted as "real", prices rose and the number of farms mushroomed to more than 2,000 by the turn of the millennium. Prices consequently plummeted and by 2006 there were only about 800 farms remaining; but their crop in 2007 was worth more than US$100 million (!)

In the Cook Islands, blacklip shell collection became an important source of income after World War II, until collecting in the main lagoon, Manihiki, was closed in 1957 to protect the remaining pearl oyster population. Shells were once so plentiful that they could be taken by the basket by wading in the shallows. However, they were still abundant in the deeper areas that were untouched and were a source to replenish the upper areas.

The success of blacklip pearl farming in Tahiti encouraged the Cook Islanders to take up this enterprise. By 1985, with help from Japanese technicians, several private farms in Manihiki were harvesting their first crop of cultured black pearls. The income was astounding, especially from a local viewpoint. The Cook Islands had been struggling to find exportable products since they became a British protectorate in 1888. Naturally, interest in pearl farming spread rapidly to the other islands of the country. Currently, however, the Rakahanga area is the only other significant pearl producer in all the Pacific islands and total production in 2007 at some US$2.2 million pales in comparison with the Tahitian pearl industry.

Closer to Papua New Guinea, spat collection trials in the Western Solomon Islands in the 1990s showed that blacklip oyster spat settle all year round and during summer in sufficient numbers to provide stock for village pearl farms. This area is close to the eastern edge of Papua New Guinea, so it is likely that there is potential for blacklip farming in Bougainville or further along the island chain in Papua New Guinea, on Latangai Island or New Britain. But in 1972, when I arrived in Port Moresby, none of this was known or suspected.

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Goldlip, or silverlip, pearl oysters (*Pinctada maxima*), are the other major type of tropical pearl oyster farmed at present. Their range is across the western tropical Pacific and South China Sea as far north as Burma (Myanmar) and down the northern coasts of Australia. Goldlips also occur in northern Vietnam and the southern coast of China. They were out of reach of the ancient pearl markets of the Roman Empire, although goldlip pearls were surely known in early trade from the Middle East down the coasts of Southeast Asia.

For more than 100 years, the main sources of goldlip oysters have been on the northwestern coast of Australia, where they were first discovered by an enterprising sailor in 1861; and the Coral Sea between Australia and Papua New Guinea, where pearling grounds were found by another wandering entrepreneur in 1868. Fleets of pearling luggers grew and fanned out from Broome to Thursday Island over the next 50 years, seeking at different times the moderately valuable shell and the occasional prize of a good pearl.

From these grounds, live goldlip pearl oysters have been transferred around the tropical Pacific in attempts to establish them in other countries or for pearl farming. As early as 1904, live goldlips went half way across the Pacific to the remote Cook Islands where they were introduced by Saville-Kent; another attempt the same year to introduce them into the Gilbert Islands (now called Kiribati) also failed. During 1935–1942, countless thousands of goldlip oysters from northwestern Australia as well as Indonesia were taken to Palau for pearl culture by Japanese companies. World War II ended that very successful venture. Nevertheless, Japanese companies retained control of the pearl culture industry elsewhere well beyond World War II.

Australian goldlip pearl farms developed in Western Australia in the 1950s in joint ventures with Japanese companies and the Australian enterprises have now their own joint ventures in Cambodia, Indonesia, Philippines, and Myanmar, and Vietnam.

The centre of my attention—in more ways than one—was the Japanese goldlip pearl culture farm in Port Moresby Harbour. Set up in 1965, the company's first trials exceeded their most optimistic expectations and they quickly expanded the farm to accommodate some 150,000 oysters. These were brought in several shipments each year from Kuri Bay in Western Australia, a seven-day trip, in two specially constructed vessels.

Enter a young spy. My idea of spying was not quite like that of James Bond in the movie *On Her Majesty's Secret Service*, released just a few years before I reached the territory. The plot of the Bond movie was the threat by an arch villain to release a plague if he was not given a huge amount of money. Eerily, a plague of sorts, similar to that in biblical Egypt, was on its way to Port Moresby—an outpost of Her Majesty's Empire—though I could hardly blame the pearl company.

My idea as a novice spy, was first to look at the government's paperwork. The early years of the farm's pearl operations were well detailed in reports by a government officer: number of oysters shipped, number with pearl nuclei inserted, numbers dead or that rejected the nucleus, and so on. But most of the information came from the company office downtown, not the farm site. Strangely, there were no reports of pearl harvests or sales. And the reports ceased in late 1968. The government officer, my predecessor in one sense, had left.

No wonder some government officials were worried. There was a black hole covering more than three years.

It was a few months after my arrival before I had an excuse to visit the farm. My report to the research director in mid-April (1972) was rather bland:

> "I have had some liaison with the pearl farm across the harbour...I was lucky enough to have a long discussion with professor Wada, and learnt a lot about his techniques that has never been put into writing. He was here for two months, has now gone back to Japan, and returns in six months time. They have a small but efficient laboratory where I saw goldlip cultured to the spat stage."

What I did not write, I related in person to the director. Professor Wada was the most respected pioneer of pearl culture in Japan and in the world. His presence meant that the farm was in earnest. I was able to see most of the farming operations and the surrounding area, including laboratories and rafts. There was no evidence of any other activity and there were few buildings other than the laboratories and staff housing.

There was quite a bit of security—guard houses on some rafts and a lookout tower. This was understandable, I explained, given the value of the pearls growing under the rafts and the large local population subsisting in villages around the harbour. Secrecy has always been a hallmark of pearl culture. I reasoned that we had no need to imagine any more sinister purpose.

Before I went back to the research station, I asked around the department staff in Konedobu if there were any more files on the pearl farm that we may have missed. One clerk looked at me in surprise.

“Of course there are. That farm is a big business. Whoooo, I would love one of those pearls. They make thousands of them.”

“How do you know?” I asked.

“My friend in the taxation department, he tells me. That’s where you will find all the paperwork now. We handled it before when they were experimenting. Now they are commercial. Must be more than three years since we had reports from them.”

There were some red faces around the department after I pointed out this situation to the director. I was released from the role of spy and left to work as I pleased, within reason, on the territory’s shellfish. But, the following week, the deaths of the three children were to give me another new role, that of detective.

I did visit the pearl farm in the harbour several times in the following months in my detective role. The farm must have been at or past its zenith at the time; by 1975 it had closed, apparently for economic reasons.

There was only one other pearl farm in the territory, that of Denis and Yuli George in their small operation in Samarai. They were the only independent pearl farmers in the Pacific. Beginning in the 1960s, they saw sensibly that a lasting pearl farming operation would only be possible if the local population became involved. They set up village cooperatives to tend to oysters that the Georges “seeded” for them on a profit-sharing basis. However, the Georges did not get the necessary government support to develop the village farms properly and their own enterprise as well as the village farms collapsed in the 1980s. A new farm in Milne Bay, based on their experience and using hatchery techniques to grow goldlip pearl oysters, began in the late 1990s. The early success of this farm has led to more applications for pearl farm licenses in the country.

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Collecting pearl oysters from the sea bed is not straightforward either. No doubt in centuries past some shells were harvested using dredges, nets, scoops, and long tongs. Early divers descended and stayed down as long as they could on one breath, probably with very limited vision. Before glass and wood goggles, as still used by the Badjaos of the Philippines and Borneo, one method was to add a few drops of oil into the eyes before submerging; another method was to blow a small bubble of air into one hand cupped around one or both eyes, leaving one hand to harvest shells. Later came diving bells and then the more portable "hard hats." Diving bells and hard hats were kept filled with air from a pump on the surface. Before World War II, when the technology improved, the pumps were manual; your life underwater depended on the person turning a wheel on deck—someone you would want to stay friends with!

Even during the past century, pearl diving remained a difficult, unpredictable, and dangerous business. The classic story of the Australian pearling industry for goldlip oysters by Ion Idriess about diving conditions around Broome up to the 1930s is one of danger and death. Stories of whales rubbing against and breaking air hoses—these were the days of hard hats and lead boots—sea snakes and sharks, not to mention storms, currents and the effects of the "bends", a debilitating illness from staying too long at depth underwater; the safety limits were unknown then and only determined by individual divers on a trial and, more often than not, error basis.

Many divers died, as attested by rapidly growing cemeteries around the pearling towns. In the late 1970s in Broome, where the street signs were in the five languages of the main nationalities of the pearl divers, I saw one of these cemeteries where one could see the different burial practices of different Asian cultures. But it was decrepit by then; bottles of beer cemented into place as drinks for the afterlife were all broken, and overgrowing weeds everywhere covered the graves of long-forgotten divers, testimonies to the dark side of the romance of the pearl.

Although diving gear improved over the years, it was still a hazardous occupation. The Australian Government was actively involved with its own survey vessel, the Paxie, up to the 1960s. Vern Wells, the commonwealth fisheries officer involved, told me about one memorable diver in 1956, who could never manage to get the diving signals right and made up his own, such as 8 tugs on the life line for “danger bring me up”. Vern kept pointing out that all the tenders can do is bring a diver up and one tug was the signal for that. This diver also usually found conditions on the bottom more dangerous and difficult to work in than that reported by any of the other divers and complained about the tide and the amount of air hose out, etc. He must have bluffed his way into the job, Vern said, as he didn’t know to close the helmet valve when descending or to inflate the half-suit to assist the tender when ascending.

Vern wrote that this diver “romanced considerably. In the first three days of the last cruise he saw more monsters of the deep than most other divers see in years. He was ringed by four groupers and several large sharks; he was getting away from a large moray eel when an immense hammerhead shark with eyes as big as saucers came at him out of the murk; a big tiger shark came and nudged him whilst staging; he put his hand on a coral snake coiled up in a figure eight while he was feeling behind a piece of coral; chased a big squid away; and on the last day maintained he was bitten by a coral snake with a head as big as your fist!”

Pearls are still sought by diving, off Western Australia and elsewhere of course, for pearl culture, but with modern technology and better knowledge of diving effects on the body; it has become a relative safe business.

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Pearl oysters generally live at depths of less than one to more than 60 meters. If I were to delve into their world effectively, I would have to learn to scuba dive. However, in the territory there were no dive shops, no dive clubs and no diving regulations.

Ernie, the sometime skipper of one of the larger research boats, became our diving instructor. Ernie was a cantankerous, limping, British ex-frogman from World War II who got by in the territory with a mixture of legitimate and nefarious enterprises, one of the more harmless of which was to look after the diving equipment and divers at the Kanudi research station.

His instruction course was good and fairly complete. We went through the basics on a blackboard in the station's boatshed. I remember my impatience, sitting on the edge of a rusting metal chair in the dark salty room, to move on to the practical classes. We were two students, me and my assistant Jon Peters, a burly Australian with an easy-going nature that could tolerate almost all of Ernie's moods.

Meanwhile, I was a little apprehensive of the dangers of the sea, the memory of a nearly fatal moray eel bite a year earlier strong in my mind. At that time I was with the Australian Fisheries Division in Canberra and took the opportunity of a band engagement (in which I played piano and trumpet) at a golf club in one of the nearest coastal towns to Canberra, Narooma, to do some snorkelling and maybe catch a few fish for a marine aquarium that I wanted to set up—I was missing the sea badly.

From Narooma, I drove to nearby Mystery Bay, a picturesque inlet a few kilometres along the coast where the contours of the shoreline suggested good snorkelling. I eased into the cold water and began an exploratory circuit of the kelp bed near the entry point. I had only gone a few dozen meters when something green shot out of the kelp and bit my inner thigh. There was blood around me immediately, oozing from a hole in my crutch. I staggered out of the water, stemming the flow of blood by putting a finger in the hole. Seeing a woman nearby, I asked for help. It was pretty obvious that, despite my stance, with a finger pointing into my crutch, I was not soliciting her and she quickly helped me get my gear into my car and drove me in the car to the doctor's office in Narooma.

The doctor and his nurse were hardly sympathetic. I lay there on my back, naked, while they sniggered at each other and put three stitches across the wound.

"That green thing you saw was a green moray eel. We get aborigines in from time to time with pieces of their fingers missing" the doctor told me between sniggers and snips. "They reach into crevices for abalone or mussels and if there is a moray there...", he made a scissors motion with his free hand.

They were unimpressed by the fact that the bite narrowly missed the femoral artery. A few millimetres to the right and I may well have bled to death before reaching their clinic.

The nurse held up my swimming costume. She pointed to the two parallel cuts across the lower front. The moray's teeth had also narrowly missed my scrotum—my balls.

"I'd say you were *very* lucky you didn't lose something too", she laughed. The three of us were in stitches by the time they finished, but I still wasn't laughing. I had a bulky bandage in my crutch and had to hobble out, legs apart.

That night I had to perform in the band at the local golf club. Dressed in a dinner suit complete with bow tie, I must have looked like a penguin as I hobbled toward the bar. The waiters were laughing loudly.

"What 'appened to you sport?" one shouted, attracting the attention of the whole club.

"'E looks like 'e's just been castrated", shouted another.

My reply: "Well, it was pretty close", was drowned in the general guffawing.

The whole back of my leg became stained purple and yellow from internal bleeding; it was months before the colour and the jokes finally faded away.

Consequently, my first open-water dive, off Port Moresby, was nerve-wracking even before I hit the water. I was diving with Ernie from a 12-meter research vessel onto a reef I could not see. The water was murky and the top of the reef was 22 meters deep, Ernie told me as he climbed into a drysuit, a thick rubber affair that gave plenty of protection and left only the hands and face exposed. All I had was my costume and a T-shirt. The wind was up and the sea choppy. It was not at all like the swimming pool where we trained.

It also seemed deep for a first dive but there was nothing to worry about, Ernie said; he would join our wrists by a longish rope so I would not get lost. There was another rope around Ernie's waist; the other end of that rope was on the boat so that Ernie could send signals. We jumped in and Ernie attached the ropes that would hold us all together. Then, to my horror, one of the crew handed him a long saw. Before I could ask what the hell that was for, he submerged, taking me with him like a balloon at the end of a tether.

The noise of the regulator, the speed of descent and the dark green gloom terrified me. I tried to imagine what relatives of morays there might be in midwater. We found the reef quickly though. It looked hairy, festooned with large sea fans and soft corals. Not to disappoint me, a large moray came half way out of a hole to look at us. Now I was really scared and kept the rope between us tight, with me as far from the reef as I could get. But Ernie then swam down amongst the coral, drawing me closer to the reef, and began to saw off a beautiful yellow sea fan at its base. I hovered, wide-eyed, above him, searching frantically for morays.

Suddenly, Ernie began to thrash around and black fluid oozed from one of his hands. He had cut himself badly with the saw. "That's all I need", I thought, recalling from zoology lessons how sharks quickly home in on struggling or bleeding fish. The next minute we were being pulled to the surface much too fast. Ernie above me was being dragged by his waist, with his legs and arms wide apart, the saw in one hand and the big sea fan in the other; his blood, becoming red now as we rose, streaming down through the fronds of the fan. I was being pulled by one arm with Ernie's saw wobbling not far above it. Meanwhile the fronds of the fan were rubbing all over my head and shoulders, stinging me; I tried to fend them off with my free hand.

I reached the surface only a second or two after Ernie but by then he had already launched into an amazing tirade in English and Pidgin against the blank-faced islander crew. His swearing and invectives went on and on as we were dragged aboard, while he struggled out of the drysuit and as he wrapped a cloth around the bleeding hand. Then he gave the order "home". The anchor was raised and we steamed the short distance back to base in welcome silence. I didn't dare ask what it was all about.

Next day Ernie told me in his colourful way what had happened. He had a customer in Australia for all the black coral he could send. The fan we collected on our dive was an unusually large and valuable specimen—in life they are covered in yellow polyps. When he cut his hand, however, his thrashings sent signals up the rope. The crew— who could blame them for being alert—mistook the tugging as the signal for an emergency ascent, and hauled us up as fast as they could. I began to laugh as I remembered the crazy ascent, Ernie helplessly spread-eagled above me, but he cut me off with a glare. I could see it was a dive he wanted to forget. Since there was no certification process anyway, I was now on my own.

We had learnt to dive according to the equipment available, that is, with steel scuba tank and regulator, nothing else (i.e., no tank pressure gauge, no depth gauge, no buoyancy vest or dive timer, no weights, let alone someone in the boat in case of emergency). My assistant Jon and I began to work on the silty bed of Port Moresby Harbour at around 20 meters. We would ascend when one of us ran out of air. Diving was simple then. Dangerous too.

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Japanese companies, ever since Mikimoto's pioneering enterprise, managed to control the prices of pearls by not flooding the market. However, pearls began to be farmed all around the Pacific from the 1960s: young blacklip oysters for pearl culture were found easy to collect from the wild by the thousand, culture techniques to breed goldlip oysters were ironed out in the 1990s, and the Chinese began to mass produce cultured pearls as large as the Japanese cultured pearls by the million from freshwater clams and without any market controls.

Consequently, pearls have lost much of their glamour, mystery and romance. The aura of pearls now is mostly an ongoing construct of the advertisers' and pearl companies' vivid imaginations. The plain fact is that (spherical) pearls today are virtually all cultured, that is, made by taking a pearl oyster out of the water, strapping it onto a work bench, prising open its shells to stuff a sphere into it and later prising it open again to recover the sphere with its very thin coating of nacre.

Like expensive sports shoes and watches, the product itself is now quite cheap to make and is mass produced; the cost, the high price that people pay now, is to cover the advertising to pretend there is still something special about them. Well, there is; pearls are still made underwater where oyster illnesses and other "externalities" are hard to control; but like a labour strike in a Nike factory, such issues raise few ripples in consumer consciousness.

Yet, the hazards of tropical pearl farming are not for the fainthearted. For instance, a goldlip farm was set up in Sabah, Malaysia, in 1993, with help from Japanese technicians from a Japanese-run pearl farm in the area that had been operating since the 1960s and recently closed. First, the new farmers found that the goldlips would not accept the inserts or grow pearls for some time. When pearls were produced, some staff began to steal them, an easy and tempting matter given their allure and small size. Even piracy became an issue for the island-based farm, already facing logistical problems in its offshore location. Finally, red tide killed nearly all the oysters in 1996 and again in 1998.

There are now much more valuable commodities to be had, from uranium yellow cake to heroin, that retain strong elements of danger, although the romance element, outside the cinema, has been replaced by insanity. In fiction, the Filipino Castilla Toledo in Ion Idriess's *Forty Fathoms Deep* and a few years later the Mexican Kino in Steinbeck's *The Pearl* show that the intoxicating power of a pearl even in comparatively recent years (the 1930s and 1940s, respectively) was not unlike that of drug dependence.

For me, tiny telephones with which one can talk to and see a caller almost anywhere in the world, send messages and store them by the hundred, tell me the time in the different time zones with incredible accuracy, while taking and archiving thousands of extremely high-quality photographs and hours of movie-quality video; storing and playing in near-original clarity massive amounts of music whether symphonies or soul; providing access to the world's knowledge through the internet; functioning as a diary, a calendar, and providing a more reliable reminder than an efficient secretary and alarm clock combined (and these are already yesterday's cellular phones), ought to have left cultured pearls in a bin in a side alley of history in terms of value.

The sale of the late actress Elizabeth Taylor's pear-shaped pearl for nearly $12 million in December 2011 seems to shoot that theory down but the Korean buyer was investing in history more than karats—the La Peregrina pearl had been a favourite of royalty for centuries before reaching Hollywood.

In 1972, interest in farming pearls was about as intense as it ever was. The Japanese still held almost exclusively the secret techniques needed to manufacture pearls and they were forming joint ventures, like the one in New Guinea, so their companies could take advantage of the South Sea pearl species, the goldlip, or silverlip, whose pearls were of colours and lustre and size far surpassing Mikimoto's pearls.

Where do pearls come from?

Pearls obviously come from pearl oysters. But beyond that, there have been fascinating interpretations of nature and the case does not appear to be yet closed. According to the wisdom of the day 2,000 years ago, pearls were produced seasonally when the oysters rose to the surface and gaped to receive drops of dew, which grew into pearls. The quality of the pearl therefore, depended on that of the dew; pure dew on a fine morning produced brilliant white pearls; if muddy or the weather was threatening, the resulting pearls were pale or yellow. But the oyster must return to the deep, out of reach of reddening sunbeams, to produce the finest pearls.

It was another 15 centuries before another theory of pearl formation became popular, that pearls arose like eggs in a chicken; it was still believed that some if not all pearls were soft when first harvested. And many preferred the more romantic dew drop story. When John Milton wrote in the seventeenth century "these pearls of dew she wears," he was no doubt harking back to this story.

In the mid-nineteenth century, a third theory was suggested, that a parasite might be responsible. Scientific studies in Ceylon (now Sri Lanka) in the early twentieth century allegedly showed that the nucleus of every pearl was the globular larva of a tapeworm, leading one French writer to conclude that the ornament associated throughout history with beauty and wealth was nothing but "the brilliant sarcophagus of a worm." It would be a fitting end to the pearl origin story—the layers of nacre around the encysted tapeworm eerily similar to the wrappings of a mummy in ancient Egypt.

The wisdom of today is still not conclusive. Many believe a pearl to be the result of an irritant—a piece of foreign material, although not a parasite or not necessarily a parasite—becoming lodged inside the oyster's tissue. If the oyster cannot remove it, the offending material is buried and covered with nacre as in the tapeworm theory. But recent investigations conclude that there is no nucleus at all in a natural pearl. The oyster, the latest researchers say, can easily rid itself of foreign matter. Instead, it forms a pearl in response to damage to the nacre secreting tissue, the mantle. The report that presents this conclusion hedges its bet, however, by saying that perhaps sometimes, an inert irritant like a grain of sand can become a pearl nucleus. We don't seem to have come very far in understanding the origin of pearls in 2,500 years.

Growing the goldlips

Culturing goldlip pearl oysters was the dream of the pearl industry in the 1970s. The huge Japanese pearl industry was based on a much smaller pearl oyster that Mikimoto used for growing perfectly round pearls so similar that pearl production became like an assembly line; it made their pearls justifiably famous, if overpriced. Yet, these greyish-silver, and small Japanese pearls literally paled next to the massive, deeply lustrous silver and golden pearls from the goldlip oyster. The Latin species name of this oyster 'maxima' says it all: maximum appeal, maximum size, maximum value—goldlips had it all. It was big business.

The problem was first that goldlip oysters were found only in certain parts of the South Pacific Ocean and eastern Indian Ocean, and second that they could not be grown like edible oysters on poles, where baby edible oysters and, indeed, other kinds of pearl oysters including the Japanese species, would settle after their initial floating stage. Both edible and pearl oysters reproduce by shedding eggs or sperm into the water, where fertilization takes place. The sea as a womb nurtures the resulting larvae while they grow, feeding on tiny algae and later on animals tinier than them in the plankton—of which they are also a part—until the urge to settle on the seabed or some immobile object overcomes them. The newly settled ones are, like edible oysters, called spat.

Pearl oysters put out some fine anchor ropes, the byssal threads, once they settle, to attach themselves to their chosen substrate. Like edible mussels, they can still move with these threads, albeit very slowly, to find the best position to catch plankton amid the moods of the tides and currents. Only the goldlip pearl oyster has no byssal threads as an adult, losing them when about three years old, after which it lies freely on the seabed. Why, no one can say. Well, that is a poetic answer. Researchers now say the reason is because the goldlip oysters are then heavy enough not to be swept away in currents. I'm not convinced; no harm in a little security.

Neither, in those days, could goldlip oysters be commercially cultured in the laboratory through artificial "insemination" like the Japanese pearl oyster. Goldlip oysters had to be collected from the sea bed as large juveniles or adults and held in cages to acclimatize before implantation of a nucleus around which the pearl would form.

As I mentioned, Japanese-run pearl farms were extremely secretive in those days. The technicians were all Japanese and they jealously guarded their knowledge about making those magnificent, lustrous round pearls of the goldlip oyster.

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One of my first objectives was to find a local source of adult pearl oysters. Initial exploration around Port Moresby Harbour for adult goldlip oysters drew a blank. That was disappointing because there up to 150,000 adult goldlip oysters hanging side by side in the nearby pearl farm. Were they all celibate?

Blacklips were more promising. Within a month of starting work, I had several dozen adult specimens in indoor or outdoor tanks and in cages in the harbour "in reserve" for spawning trials. Given the amount of effort to find them though, the numbers were disappointing.

The blacklips were collected during surveys of the reefs off Port Moresby and nearby bays. I had teams of up to 8 local divers using masks and snorkels spread out over the corals. I'm sure their eyes were much better than mine. But, their catch was never great; in fact it was consistently small: "6 divers took 30 shells in 2 hours"—

that was the record; the average of 103 diver hours over a 12-month period was only 1.2 shells per hour per diver. Neither were blacklips seen in abundance anywhere else in Papua New Guinea where we snorkelled or scuba dived; nor was there any information forthcoming about concentrations of them anywhere in the islands.

The other way to gather pearl oysters was to collect their spat. I attempted this with a variety of novel spat collectors, although I stopped short of false teeth. Generally, pearl oyster spat liked to settle on shady rather than sunny places and that was about all the information I had.

The literature was virtually blank on what collectors others had tried in order to attract baby goldlip oysters to settle. However, I had heard that in Polynesian lagoons, abundant blacklip oyster spat could be collected easily on hanging rope collectors. Of course, this success depended on the very large stocks of adult blacklips spawning during most months of the year. There was no evidence of any large blacklip population within reach of Port Moresby.

We suspended below buoys in the harbour coir ropes, fibro plates like those for edible oyster spat collection, open ended plastic pipes, and fibreglass cones of the type being used to mark the boundaries of landing strips at airports around the country.

A few weeks after the first collectors were installed, I thought I had hit the jackpot in a major lottery. We began to find vast numbers of pearl oyster spat all over them. I imagined our own, that is, the government's, pearl farm arising along the harbour shore, local enterprise triumphant over the secretive Japanese farm nearby. These little oysters covered our collectors, whether fibro, coir rope or fibreglass cone and whether intertidally, near the surface or 10 meters below it.

We measured everything there was to be measured: their heel depth, maximum diameter, hinge line length and top-to-bottom length by, the hundred and placed them in cages near the wreck of the MacDhui. Alas, they did not grow to become prize pearl oysters.

They began to mature before reaching 20 millimetres in length and soon died in the cages; the biggest that remained on the collectors were only 75 millimetres long. After that they disappeared. They were identified eventually by technicians at the local pearl farm as *Pinctada fucata*, a close relative of the Japanese pearl oyster; their life span was probably less than a year. In the meantime, my notebook was filling with their measurements and their reproductive state. They appeared capable of spawning during most of the year, which would explain their constant and abundant presence on the collectors.

In fact, from all our different types of collectors in the harbour and nearby bays and in the Trobriands, we never found spat of either of the two species we were seeking for pearl farming. Later, I read with some satisfaction that goldlip oyster spat collection attempts in Australia, even in the pearling grounds off northwestern Australia, were unsuccessful, allegedly because of the strong currents. The researchers had to make do with the rare appearance of spat that settled on the shells of adult goldlip oysters.

Over time, the results of the plankton samples from the harbour and the data from various types of collectors I placed there were beginning to tell me the same thing: neither the vast numbers of nearby goldlip pearl oysters nor the scattered blacklip pearl oysters were producing larvae, or if they were, it was in inconsequentially small numbers.

If those goldlips decided to spawn, the water would be teeming with larvae for some time—several weeks was the norm for most bivalve molluscs—before they settled. And because the harbour was semi-enclosed, the water currents would not be strong; the larvae would not be whisked away to sea overnight.

Later research showed that goldlips spawn during at least seven months (September to March) of the year in Western Australia, with peaks near the beginning and end of the “season”. Also, each oyster spawns several times during the season, just like my winter whiting fish from Moreton Bay, and females produce up to 12 million eggs per spawning. I thought about the effect on Port Moresby Harbour water and other marine inhabitants of 100,000 female pearl oysters suddenly spawning in the confines of the farm; you could probably walk across the water.

Goldlips have been found to do a sex change. They grow slowly, 2.5-5.0 centimetres a year, and change from being males in their early years to females as they grow older, living up to 20 years. It is probably not something to tell your partner as you slip an expensive goldlip pearl necklace around her throat.

In retrospect, Port Moresby Harbour's hydrography was probably a major factor in dissuading the goldlips from spawning. The oysters were suspended in perpetual suspense, waiting for a current that never came. In their home grounds off Western Australia, the water was often moving at fast speed; the tidal range on that coast, 10 meters or more (!), gives some indication of just how fast that must be. Oceanic conditions in Western Australia versus almost estuarine conditions (that is, when seawater becomes diluted to variable extent by nutrient-laden freshwater runoff from land or rivers) in Port Moresby Harbour undoubtedly represented another constraint, perhaps the final blow, to the Port Moresby goldlips' sex life.

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Putting myself in the place of a local person wanting to make a pearl farm, I would first need stock and somewhere to put them. I had some cages ready at a marked site in Port Moresby Harbour, 20 meters down on a sandy bottom. But I would have to look elsewhere for the stock. The pearl farm in the harbour was not going to give away any of its valuable and hard-won stocks from Western Australia.

From correspondence with the only other pearl farmer in the territory, Denis George, I learned that there were goldlip stocks in the China Strait, a passage between the Coral Sea in the south and the Solomon Sea in the northeast. Seven kilometres long, it was a hazardous short cut between the two seas, especially for allied submarines that used it frequently during the Second World War.

The tiny, only 24 hectares, island of Samarai, at the eastern end of Papua, lay at one end of the China Strait. You could walk around the island in 20 minutes, if you stopped to chat with villagers on the way. Yet it was one of those colonial administrative outposts through which one passes to pay respects and let the government know what you are doing in the area. It was a charming village in 1972. Most houses, nearly all plywood or concrete affairs, had only curtains for doors. They may have had doors that they shut at night or during storms but the friendly atmosphere was completely different from the ‘boy wire’ mentality of Port Moresby.

Denis George and his Japanese wife Yuli, with their three lively sons whom Denis called the terrible trio, lived by their small pearl farm on an even smaller island of their own close to Samarai; Pearl Island they called it—what else? The name was probably a conscious copy of Ojima Island in Japan, where Mikimoto grew his first pearl and which was later renamed Pearl Island. The George’s island presented an inhospitable vista to the visitor. It was narrow and consisted only of a sharp spine rising up from one end with steep tree and shrub covered slopes, almost cliffs, down each side. The Georges lived in two native style huts perched along the spine with lovely views of Samarai and the China Strait; the climbing kept them fit, they said.

Their pearl farm, at the foot of the gentler sloping end of the ridge, was a series of ropes holding the pearl oysters at different depths. The ropes were draped off rusting World War II barges lying in the water at odd angles. These tattered brown wrecks gave the farm an air of sad impermanence, but they had endured the corrosive sea for 30 years already. One of the barges formed a lopsided pier—a simple arrangement; the sort of thing that we would call appropriate technology for the conditions.

At the time of my first visit, the Georges were making their cooperative venture with the nearby villages; the Georges and their crew would collect pearl oysters from the bottom of the China Strait, glue half-pearl nuclei (a half-sphere of soapstone, pearl shell or resin) inside the shells and pass them to villagers to look after for the 12 to 18 month growing period. Denis and his wife would then take the harvested shells, cut out the half-pearls with a keyhole saw, and polish and market the pearls, sharing the proceedings with the villagers.

I visited the family several times, rented their pearl diving boat and gear, bought a few nice pearls from them, and tried to intercede with the Papua New Guinea and Australian government on their behalf to get the village-based association of pearl farmers moving. I sent Denis photocopies of articles related to pearl culture to overcome his isolation ("Do you have in the Department library any further interesting literature? You know how much mad I am in collecting them", he once wrote.)

Denis hoped to attract local residents into contract or share farming. He was hoping for a government grant to get the scheme moving. He made great progress while I was there. In March 1974, the grant looked doubtful, but he was in full swing and I admired him for it:

> "So far, no money from the government….the refusal of the grant would make things a little harder but it will not stop us!"

My first visit to the George's pearl farm was with Ernie to collect goldlip oysters for my little farm on the bottom of Port Moresby Harbour. Collecting pearl oysters from the China Strait proved to be an eye-opener. Denis had agreed to help us and rented us his boat, a working catamaran with a large compressor on the back deck. He was too "bent"—had suffered several times from the bends or decompression sickness—to dive anymore and normally sent down one of his trained villagers. The oysters, he told us, were found on the bed of the strait, which was flat.

According to Denis, there were plenty of gold-lips down there, looking like big brown dinner plates lying on the bottom; you could simply pick them up. There were two small problems; the current through the strait ran at an undiveable 4–6 knots and the depth was around 40 meters.

We chugged out into the current, making little headway. After some time, Denis ordered his crew to drop the marker buoy. The buoy consisted of two large, glass, Japanese fishing-net floats strapped together with a long pole and a flag atop it. At the other end of the ropes was a prodigious amount of weight to be thrown overboard. We watched as the buoy was deployed, the floats bobbing along and flag hanging down into the water, drifting away from us. Suddenly the flag turned upright and the whole thing disappeared, floats, flag and all. Some current! We motored into the lee of an island and anchored where we could watch the place where the buoy had vanished.

"The current is mainly tidal", explained Denis. "In a little while the tide should be changing. Then the floats will surface and that is when you can dive."

"And how long before the current picks up again?", asked Ernie. "How long can we work down there?"

"Well, about 15 minutes if you are lucky", Denis said apologetically.

We had a smoke while Denis told us about the potential of the new cooperative; it could multiply his output and bring good money to the area. We nodded enthusiastically. Nevertheless, I had private reservations about the effect of money in rural villages. It was bad enough in Port Moresby. Pay day was a time to keep off the streets. Those receiving salaries were swamped by their wontoks—relatives or simply people from the same village, asking for their share. Most of those shares and what was left for the salary-earner went quickly, on cases of those SP greenies and brownies, most of which was drunk the same night. As I mentioned, one of our staff was killed outside the nearby trade store in Kanudi in a drunken pay day scuffle. It was sad to see their pay squandered like that and the effects it had.

My musing was interrupted by a shout from one of the crew. There was the flag, just coming out of the water. The anchor was raised, the compressor sprang to life and we moved toward the buoy while Ernie attached himself to the hookah unit, in essence a regulator at the end of a very long hose. The hose ran down from the regulator under his crutch and up his back. It was strapped back and front around his waist. A separate rope was also tied around his waist for a safety line as well as an attachment for the basket of shells he would collect.

"What happens if the compressor stops?" I shouted over its clacketing, thinking about the reliability of two-stroke engines in tropical salty air and the lack of parts, let alone maintenance.

"There is a reserve tank", smiled Denis. "No worries," he added pointing it out.

"How long would that last a diver?" I asked seeing a cylinder not much bigger than a milk bottle on the side of the unit.

"At least a minute", he replied.

If the crew were not alert, it would not matter anyway at 40 meters. If they were, you would be dragged up at a rate which would cause the bends. Denis didn’t mention the cause of his bends, but he was a long-time pearl diver in Australia as well as in the territory and probably made many risky dives.

Ernie leapt off the boat with his basket and enough weights to carry him down (but of course no buoyancy vest in those days) as the floats began to make their appearance. I watched the plastic hose snake down after him, rattling as it went over the gunwale. I didn't envy him.

Minutes dragged by. The flag reached its zenith and tilted in the other direction as the current strengthened. Ernie gave a signal on the rope and after several minutes appeared, smiling with his basket full of pearl oysters, nearly two dozen. I supposed there was no black coral to distract him.

"Okay, mate, you're next", he said as he clambered onto the deck. My heart and lower intestine gave notice that this was foolhardy.

"No way", I said. "Look at the buoy, the bloody floats are nearly underwater again."

"Listen sport, we're doing this for you, right? You have to take some of the risks as well. Now get down there. You need another dozen shells. Here's the basket. Better get moving fast."

I must have been still arguing as I fell and finned downwards, trailing the long plastic snake above me with nothing else visible in the bluish expanse. The bottom eventually came into view. Only then did I realize to my horror how fast the current was. I did not need to worry about crashing onto the sea bed. The current was hurling me along at an incredible rate. It was like an old movie where the actors are meant to be travelling at high speed but actually remain still while the background is moved past them. I felt no motion. The boat, the whole water column and I were moving at the same speed; the bottom, meanwhile was zipping past like a high speed conveyor belt. Fascination overcoming fear, I tried to make out what forms of life there were around me, but the sea bed was just a blur and I became mesmerized. The next second I was being hauled upwards faster than I would have liked even if I did want to leave the bottom.

Ernie and Denis were laughing when I surfaced. They knew it was impossible to collect shell once the floats had gone under. Nevertheless, Ernie wanted to regain the face he had lost after my first dive with him.

"Well, where are the shells?"

"You didn't give me enough time", I retorted.

"Crikey, you were down there longer than me", he shouted. I wanted to tell him where to get off but he turned back to Denis and ignored me.

We had enough shells to look after as it turned out, enough to fill a large bin. The logistics of getting them alive to Port Moresby Harbour were complicated by the small size of the available plane. We realized that it was too far to carry them in a bin all the way around to Alotau in Milne Bay where the DC3 air service to Moresby would not arrive again for two days: the shells would not survive. But, there was another way. We could catch this day's service flight by taking a plane from a small strip beside the China Strait in time to meet the DC3 at the Alotau airport.

Arrangements were made by telephone and we crossed the strait with our precious cargo in a large plastic garbage bin. Denis had to keep the boat pointing some 45 degrees upcurrent from our destination, so that we crossed somewhat crabwise. There was a long jetty to negotiate at the other end. However, there was, we were told, a tractor taxi at the shore. The tractor was waiting.

"In the back", a laconic villager told us. We threw our gear, the bin of oysters and ourselves into an open wagon attached to the tractor and set off up a hill that grew steeper and steeper. It was easy to see why a tractor was used. The last few hundred meters were so steep that even though the way was concreted, the tractor wheels began to slip; it became terrifying to look back down the slope. We came over the top to the smell of burning rubber and the sight of a tiny single-engine Cessna on a grassy plateau that seemed no longer than a bowling green.

"'Urry up", the Australian pilot drawled. "I 'eard the plane from Moresby go over already."

We dragged our gear off the trailer and heaved the bin of oysters up over the wing and behind the pilot's seat.

"What the hell's that?" exclaimed our pilot.

We told him and he made a quick estimate of the weight.

"Sorry. One of you’s has to stay behind. Or toss out them friggin' oysters. Ya can't eat them things anyway."

I turned to Ernie, the memory of the China Strait dive full upon me.

"Well, Ernie. Looks like we have no choice. You stay. See you in Moresby."

Ernie's face went as red as I had seen it in any of his altercations with local staff, but he could say nothing. I darted over the wing, sat by the pilot and shut the door. There being no control tower or possibility of communicating with Moresby over the mountains, we were very soon charging across the bowling lawn.

As the plane began to tilt back and the front wheel left the ground, my door flew open and the pilot jammed on the brakes. Seawater sloshed onto the floor unnoticed amongst the pilot's swearing. I blamed Ernie; not wishing to miss an opportunity. We taxied at near take-off speed back to the other end of the lawn, span around (more water overflowing), roared down the grass strip and this time we rose up—into the worst turbulence I have ever had the misfortune to experience. The plane rocked and pitched violently as we climbed to reach the high mountain peak between us and Milne Bay. We climbed noisily, slowly. The forests gradually fell away below us. Suddenly, we dropped out of the sky. Straight down toward those forests again.

My experience in light planes was limited to the Bush Pilot’s twin-engined plane that had lost a tank load of fuel on take off, and the small seaplane that lost its rudder in a creek in northern Queensland. You might think third time lucky. Anyway, I was not prepared to fall out of the sky with the engine and controls working perfectly.

We were caught in a severe downdraft.

"Take my bloody cigarette", shouted the pilot, as I stared at the approaching valley. He was straining against the steering column and his cigarette was burning down onto his fingers; he could not release his grip for fear of spinning out.

We levelled out a few hundred meters or so above the forest canopy. Neither of us spoke until we crossed the peak and headed down to Alotau.

"There's your plane", the pilot said as if nothing had happened. Glinting in the sun was the DC3, a Dinky toy in the distance. It was moving.

"I think we're too late", I said feigning equal nonchalance, thinking of what those pearl oysters would smell like if they died between here and Moresby..

The pilot did not reply but turned the plane downwards on an approach facing the DC3. The DC3 was gaining speed; we were flying down onto the runway toward it—in front of it.

"It's taking off", I shouted. On our present course, we would either land on it or under it.

Terrifying minutes or seconds passed. Would the DC3 pilot see us? If so what would he do? After those interminable minutes or seconds, we both gave a shout as the DC3 turned off the strip and came to a stop as we glided in past it and taxied up to it. I started to think of all the aviation rules that must have been broken.

The pilot simply said "told you we'd bloody make it" and I was out the door, dragged the bin to the open rear door of the DC3, was given an arm up into the plane and we—my oysters and I—were airborne again before I could catch my breath. I didn't even have a ticket.

Hookah diving, I decided after that experience, was not my favourite way of staying underwater. Unfortunately, there was no choice when exploring new areas around the islands. The airlines would not accept full scuba tanks and there were simply no air filling stations outside Port Moresby.

The China Strait was not going to be an easy place for collecting pearl farm stock. And the logistics of bringing them to Moresby left something to be desired. A commercial enterprise could bring a boat down from Moresby with a team and bring the shells back by sea. We didn’t have that option. Besides there were other potential sites to visit.

I visited the Georges at their farm on a few more occasions and they sometimes dropped by our house on their trips into Port Moresby. On one of these visits, Denis had some black pearls. They were the first ones I had ever seen and I was deeply impressed by their colours, which made the ordinary Japanese and even the goldlip pearls appear plain beside them. Perhaps there was something about black pearls that inspired all those stories of romance and danger after all.

The more I looked at the black pearls, the more I wanted to have one. The pearls gazed at me like the dark inscrutable pupil of a hidden eye, mutely appealing to be taken. The spherical ones were understandably very pricey in those days but some large half pearls looked almost as attractive and in the end, I just had to buy one. Later in Australia, I had it made into a ring, with gold backing to set off its colours, for my wife.

By then, I had gained a lot of knowledge about the local molluscs and especially about red tides and their causes. So the tone of our conversations was one of mutual respect when it came to our pet subjects—black pearls and red tides.

My wife wore the ring proudly at parties and various “functions” in Canberra. It was indeed an intriguing party piece and between such events was carefully put away.

One day, nearly a year after we left Papua New Guinea, the pearl fell apart. The thin layer of nacre came away from the backing. Our dismay turned to shock to see that the nacre was a pale grey colour and the deep dark violet lustre that we had admired in it was made by the colour of the filling material behind it.

When I calmed down and thought more about the pearl, I realized the backing had to be dark or it would have the opposite effect on the pearl by making it more like a silver or white pearl. So when I wrote to the George's, it was asking about their progress; what had happened since I left; and incidentally, that black pearl came apart.

Their reply, at the end of 1974, was the last correspondence I had with them. There was good news about their venture:

> "Just now all the pearl farms [set up by villagers in various sheltered sites] are in production. All of them during our periodic sampling showed good pearl formation. I am anticipating quite a few thousands pearls. The first major harvesting is due in a couple of months time. Not yet sphericals, mainly because of the lack of materials. On the overall, the development was extremely well….We have established a 'Pearl Farmers Association' and just now we are building facilities and accommodation for a number of local boys to be trained."

Their letter also included *two* precious half pearls and a note from Yuli: The pearls were replacements for the damaged black half pearl. She wrote: "I am sending one white pearl extra. This is a present to compensate for your heartache".

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After the China Strait experience, it was not long before Ernie and I were off looking for areas where other pearl oyster beds might be located. This time our destination was Manus Island, the northern tip of the Territory of Papua and New Guinea. Hookah diving would again, unfortunately, be our main tool. We charged up to the counter in crowded Moresby airport with a train of local staff carting the compressor and hoses and other diving and collecting gear as if on a long safari. We were late. The airline ground staff were tersely polite and very efficient. Our carriers left us and we began to relax as the ground staff checked and weighed our gear; it was grossly overweight, of course, necessitating all manner of paper work.

"No fuel in there, sir?" said one casually, pointing to the compressor.

Ernie, who was in charge of the equipment, wagged his head, puffing out his cheeks. He was turning pink. I recognized the signs. The bugger was either lying or he had not checked the tank. I started sweating as the man opened the tank cap and put a finger into the reservoir.

"There seems to be a little left in there. Better take it outside and drain it again", he said smiling thinly.

Our carriers gone, we lugged the heavy machine through the crowds and upended it. The tank was full. Ernie was cursing the ground staff under his breath. I refrained from calling him a fuckwit and no doubt he knew that I was refraining from calling him a fuckwit and that made him curse all the more vehemently. After some ineffectual wiping to remove the more obvious gasoline streaks, we brought the thing back to the counter where our man inspected it again and had a porter clean it properly.

By now, the plane was waiting only for us. All the other passengers were on board, watching. It added a horrible tension to the rushing and sweating we were going through.

"Just put your equipment on the belt, sir", the ground staffer told us. There was a conveyor belt beside the counter; it ran past the side of the ticketing area straight out onto the tarmac near the plane. On went the compressor, our other gear, the coils of hose and our personal bags. Off it went toward the plane. We gave a sigh of relief and turned toward the departure gate.

Behind us the belt started to make strange noises. I looked around to see one of our hookah hoses writhing and thrashing like an octopus in a washing machine. The belt came to a grinding halt as ground staff rushed over and pulled at pieces hanging out. We shouted at them to be careful—in fact, Ernie shouted a lot more than that; he was livid—but the hose was ruined by the time it was extricated from the rollers under the belt. Ernie was so wild he would not talk to me and found himself a vacant seat on the other side of the plane.

At Manus, we contacted the district office and arranged for a boat. In those days that meant an aluminium open hull with a dubious 40-horespower outboard on the back. The engine cover was invariably missing, due to the frequent need to poke around inside it to get the engine started. Ours proved to be a battered specimen, noisy but efficient.

First stop was one of a string of tiny islets that ran in a wide arc around a lagoon to the north of the main island. The lagoon was shallow enough for us to use mask and snorkel in our search but any pearl oysters here would be black lips, valuable but inferior to the gold-lip species. In any case, the villagers were not interested in pearl oysters; they wanted to show off their giant clams.

At one side of their village, in 3 meters of water, was a most amazing colourful scene. Normally giant clams are solitary beasts, sitting usually in fairly open, shallow clear waters, their mouths open, exposing wide exquisitely coloured lips. Well, that's all a giant clam is, a mouth with thick lips and lipstick painted by Picasso. No two seem to have the same colour pattern. These villagers had collected dozens and dozens of the clams, each between 30 cm and a meter wide, and assembled them all here, just outside the kitchen window, so to speak. I came up from my first dive and spluttered "It's a clam garden." There they were, all smiling upwards with their beautiful lips sparkling in dappled sunlight. I wrote an article about the Clam Gardens of Manus—such collections were unknown to science—and the term *clam gardens* has since become embedded in the literature.

The villagers were certainly pioneers. It would be another decade before western-trained researchers were to come up with the idea of giant clam farming. It was done here as a matter of necessity, one of the villagers explained in Pidgin. Poachers from Taiwan had been coming to the islands and taking all the clams, which were prized delicacies not only in Papua New Guinea. In a 1994 book on coastal management issues in the country, one Manus islander spoke about the problem, still a concern 25 years on:

> "Our problems are with Asian poachers, like the Taiwanese. They take clam shells and fish. And their boats tear up the reefs sometimes...
>
> "The other poachers mostly leave their ships out at sea, and they send in dinghies. The men on these dinghies do all the fishing and clamming and then haul the catch back to the big boat. There's no proper surveillance. Most of the time they escape."

Ernie and I snorkelled over the clams, watching the smaller ones slam their lips shut as our shadows passed over them. He climbed into the dinghy first and as I handed up my camera, there was an incredible roar and he leapt over my head, managing to fire off a few expletives before he hit the water. Behind me was an aircraft disappearing into the distance just above the surface of the sea. I was convulsed with laughter as I clambered aboard, picturing Ernie's ungraceful leap. We stood in the dinghy, looking out for the plane for a while. Ernie kept up some interesting language as he scanned the horizon. Then he calmed down and started tidying up our gear. Suddenly there was another roar. I turned to see a twin-engined plane coming right at our dinghy; its cockpit looked lower than us, and there were two men inside, grinning behind their sunglasses. Ernie and I were both over the side like the start of the Olympic 50-meter freestyle finals.

We caught up with the pilot and co-pilot that night at the local club. They recognized us and were still laughing in a good natured "did you guys look funny!" sort of way. We subdued them with some bar stools and they were pleasant enough after that. Their ploy had been to fly along the outer sides of the chain of islets below coconut tree height, so we neither heard nor saw them until the last moment.

The islands had seen their share of war, as rusting barges against the shores everywhere testified. We would have been "goners" had the attack been a real one. I chalked it up as an unusual hazard to diving, during peacetime.

Next evening we attended a night of gambling at the Australian naval base to raise money for the family of an officer who fell to his death into the hold of a vessel. It also provided an opportunity for us to borrow some scuba gear and over the next few days we explored deeper reefs on the south of the main island.

No one knew of any pearl shell grounds and our dives were fruitless. The diving itself was unremarkable and one of my main memories there was of two bearded, bedraggled Australians who paddled out to our dinghy from an adjacent island. They were school teachers for the communities in the vicinity. On the beach watching them was a slip of a New Guinean woman under a mass of hair. "She's our wife", they explained.

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Later in 1972, I heard about poisonous shellfish in the Trobriand Islands. From old colonial reports, it seemed that villagers refrained from eating shellfish during the months when the waters of their lagoon became phosphorescent at night. That was when the shellfish became poisonous. I decided to mount an expedition to the Trobriands to learn which shellfish were poisonous, gather samples and put out a collector for pearl oyster seed.

On this trip I took my assistant Jon, rather than the recalcitrant Ernie. We had the hookah gear again, repaired and carefully packed this time, equipment to check the physics and chemistry of the lagoon waters and to collect and preserve plankton, a couple of meter-tall fibreglass cones—our pearl oyster seed collectors—

together with floats, ropes and shackles to moor them, and insulated containers to bring back live plankton and shellfish. Somehow, all this gear arrived without loss at Losuia, site of the tiny Trobriand Islands airport, marked, as was the custom at rural airstrips throughout the territory, only by a symbolic fence and a bunch of fuel drums. Here I encountered the wailing man I mentioned earlier in the story, seeing off his wife.

The "town" of Losuia itself consisted of a single-storey administrative building, a Chinese trade store and scattered grass huts. The huts were miserably small and low. Cooking was done inside them so their interiors were smoky and blackened. We visited one family, from whom the district officer thought we might learn about the poisonous shellfish. The family apologized for the small hut. The problem was that the people's huts had to be smaller than that of the chief. Their chief was not very ambitious.

We did learn from them that the shellfish in question were cockles that lived under the sand in the lagoon and that we should ask the villagers in a settlement several kilometres down the side of the lagoon to gather some for us.

The government's boat was provided to us; the usual aluminium dinghy with suspect outboard, but a big flat-bottomed specimen with plenty of room for all our gear. We decided to place our pearl oyster collectors near the south end of the lagoon. On the way we would ask the villagers in the lagoon for cockles and pick them up on the way back.

Dolphins played around our dinghy as we sped down the lagoon, but they shied away when we stopped and dived in to join them. Perhaps they were hunted here. At the village, we talked to a few people on the beach in Pidgin, offering them one Australian cent for each cockle they found.

Setting out the pearl oyster collectors was a time- consuming job, finding suitable rocks to attach the ropes, getting tangled in the hookah lines, manhandling the equipment from the dinghy. There was no time to enjoy the variety of large colourful fish wandering by. We ignored them and they ignored us. We were working only 7-8 meters down and with hookah gear the diving time at those depths is limited only by the fuel supply in the compressor. We had no idea how long our dive was but despite our wet suits we were shivering when we surfaced.

Close by was a long narrow island, the whole thing a coconut plantation. It was the macro version of that archetypical desert island with its one coconut tree. On the beach, there was a gazebo screened against mosquitoes. We motored over to the beach to dry out and warm ourselves. We wanted to contact the plantation manager and let him know about the collectors; perhaps he would keep an eye on them.

As we approached the beach, we could see a man inside the gazebo. He came out and invited us in. He was Frank Holland, British, the manager, he explained; the gazebo was his office. After he had listened to our reasons for being there, he shook his head.

"So you didn't notice the shark. I was watching you out there, wondering if you would meet up with it. A big shark has been hanging around the past week. At low tide, a lagoon forms here in front of the gazebo between the beach and a sand ridge about 50 meters out. I've seen the shark cruising past close to the beach at high tides but yesterday it got trapped as the tide went out. Damn me if the thing didn't come out of the water and work its way over the sand ridge into the lagoon beyond. Weirdest thing I ever saw, slithering like an eel. I got a good look at it. It was a hammerhead and I would say it was about six meters long."

Jon and I looked at each other. Nothing was said, but somehow we never did get back to find out if any pearl oysters had settled on our collectors. However, we had the foresight to ask Frank if he would check the collectors now and again.

Over iced tea, we talked about life in the Trobriands, called the "islands of love" from a distance. The islanders had been rather on the licentious side, the manager told us, and there were festivals when the girls even chased the men. But missionaries had stopped the practices and replaced hip-hugging grass skirts with the ubiquitous "Mary" dresses, shapeless tubes of garish, usually of floral design, cotton from the trade stores. Those trade stores must have been in league with the missionaries, I'm sure.

I passed on to Frank a story I found in one of the territory's annual reports from the 1930s about the three funerals of one man in a village near Losuia. He was an old man and when he died they laid the body out on a high platform, as was their custom, killed a pig and distributed parts to the mourners to eat during the wake. Pigs were prize possessions and usually eaten only during such important occasions, when they were a welcome change from the usual diet of root crops. In the middle of all this, the old man sat up, astonishing the mourners who, nevertheless, consumed the rest of the pig in what turned out to be a celebration of the old man's mysterious recovery.

A few days later, the man collapsed and died (again). He was laid out with the same ceremony, a pig was slain and devoured. The old man awoke again. This time, the celebration was less enthusiastic, pigs being so valuable and funerals consequently so expensive for the families left behind. Thus, when the old man collapsed a third time, the report tells us, in the dry language of colonial officialese, that his family took measures to ensure that he would not rise again.

"You shouldn't have offered so much for the cockles", advised Frank as we took our leave. "We will all be expected to pay more for shellfish for a while now."

I nodded but felt that a cent each for a few dozen—if I was lucky—cockles was not likely to upset the market. We skimmed back through the still lagoon. The tide had gone out and we had to shut down the motor and paddle the last few hundred meters toward the village where we hoped to buy the cockles. It was only a few hours since we had made our request to a few people on the beach there. I will never forget the scene before us. As we paddled forward, people began to appear from the shrubbery and coconut trees that hid the village houses from the sea. Not just a few; the whole village must have been waiting and all the villagers were walking into the shallows toward us. Dozens of people, women, men and children, converged on our dinghy, carrying wooden bowls, dishes, pots and other assorted household implements on their heads, full of cockles; thousands and thousands of cockles. I only wanted a few dozen, but bought the first five hundred, a fraction of what was offered. That number filled the remaining space in the dinghy and we were able to leave the villagers without too much argument or loss of face. We released most of the cockles as we sped out of sight of the village.

Back in Losuia, villagers told us about an underground sea in a cave in the middle of the island. In this subterranean inland sea were fish without eyes. We listened politely to the stories and told each other that perhaps we would have to dive there to bring back specimens for the resident fish taxonomist in Port Moresby. Inwardly, we were trembling with excitement at the prospect! Nowhere had we read or heard about such a place. An afternoon visit was made to the nearest village and with the village chief himself we struggled through thick jungle to the cave's small mouth and peered into the gloom. It would not be an easy trip. Arrangements were made for a "safari" to the cave.

We returned next day, the government's "minimoke", something like a miniature Landrover gutted of nonessentials like doors and roof, weighed down with diving gear and lights. Our main concern was how to get the equipment through the jungle to the cave. The village chief must have shared our excitement. When we arrived, most of the villagers were waiting, the equipment was taken and spread over many hands, and we set off into the jungle. To our amazement we found that a road had been cut through the jungle overnight. For thirty minutes we walked down a broad thoroughfare that had not been there the day before. A five-meter wide section of the jungle had been hacked out by the villagers for our safari.

The road ended right at the mouth of the cave, which had also been cleared. It was now larger and morning sunlight streamed in. Jon and I removed our sandals and climbed down over slippery boulders, followed by the chief and some of the villagers.

As our eyes became accustomed to the soft luminosity of the cave, we gasped in awe. Far above us, the roof of the cave was composed mainly of pale coloured stalactites ranging in size from a few meters to huge structures almost within reach. We quickly realized, however, that they represented swords (and missiles!) of Damocles hanging over us. Reverberations from the compressor motor could bring them crashing down on us and destroy probably thousands of years worth of beautiful formations. The remainder of the cave roof was black. Looking down at the slippery ooze welling up between our toes, we also realized that the black roof was a living layer of bats and that we were slipping in bat guano that had been deposited since time immemorial.

We were conserving our lights for diving but now turned them on and directed them further down where the roof was reflected in water. There was a collective shout from the locals as the lights pierced the surface. The water was almost completely transparent and the pastel brown features of the rear wall of the cave continued down with just a hint of green coloration near the surface, turning more bluish-white with depth. But what depth! The cave roof sloped away underwater out of sight. From it hung more stalactites pointing down and down as far as our light beams would reach. Now and again, small white fish shapes would dart into the light.

We retraced our steps to the cave mouth and found that even if we kept the compressor outside the cave, we could not use the hookah to dive; the water level was too far below the height of the cave mouth. Instead we snorkelled with our lights, marvelling at the transparency of the water. It was freshwater. We estimated that we were seeing 30 meters down quite clearly. The cave seemed to turn away in a wide tunnel at that depth. It was amazing clarity, all the more amazing because the white colours of the underwater cave roof and walls reflected our light beams, revealing the whole pool bathed in sensuous pale green-blue light. The blind fish turned out to have other mechanisms to avoid being captured by clumsy divers and we soon abandoned the chase.

We later explored the north side of the island (Kiriwina) where visibility was also around 30 meters, now in blue water; we encountered a school of dolphins and another of large humphead wrasses. Oddly, much of the coral was dead and among bits of rusting steel we found small ammunition, hardly tarnished, on the bottom, left over from the World War II.

At least I had the cockles and some plankton samples to show for the expedition. The cockles were left underwater at Losuia until the day of our departure; then transferred to the insulated containers in a little seawater and sealed. One box was going to Sydney, a long journey, where a scientist had requested specimens to analyse their red blood. Tropical cockle blood contains haemoglobin similar to ours.

My cockles reached the holding tanks in Port Moresby happily. The Sydney-bound cockles were on the long hop to Sydney the same day. Those arrangements had been made carefully to take advantage of the quickest, most direct flights. The cockles reached Sydney next morning. Their box had urgent signs and full addressee details all over it. I sent the scientist a telegram to collect them quickly. He contacted the airline but their employees searched the luggage in vain; it seemed the cockles had disappeared.

About a week later, a storeman from the airline rang our scientist, asking him to please come and get an incredibly smelly package addressed to him. The storeman had come across the box deep in the bowels of the airport where it had been overlooked. The cockles perished but made their post-mortem presence only too compelling. That was science in the 1970s.

Frank Holland wrote from his gazebo on Kiriwina in October that he was hoping to get time to look at the collectors "in a couple of weeks". He sent a package of shells the following January. Once again, they were the useless small pearl oyster that covered the collectors in

Port Moresby Harbour. We never heard from Frank again after that shipment. Perhaps that hammerhead shark…

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The paucity of goldlip and blacklip pearl oysters in the areas we have visited meant that, if a local industry were to develop, the oysters would be best raised in hatcheries and later transferred to cages in the sea to ensure a reliable supply. I began spawning experiments on pearl oysters within three months of my arrival. There were already enough blacklip pearl oyster adults on hand from our early surveys to attempt to rear them in the laboratory.

The experimental protocols were derived from the hatchery manuals for various bivalves like oysters and pearl oysters. At this time, I had no food for the larvae at the time, but the best conditions for spawning and survival of the early stages could be determined while waiting for the food—algae cultures—to come from Australia.

The eggs of blacklips needed a stimulus to make them fully ripe and very weak ammonium hydroxide solution was recommended for this purpose. The first series was encouraging. Even without the ammonium, and in low doses, there was some fertilization and the eggs divided into 4 and 8 cells. But only in the highest strength (only 0.001N in chemists' terms), were later stages (trochophores) found. Thus, the next series was to test higher ammonium strengths. However, there was no fertilization at all, even in the zero and 0.001N solutions of ammonium hydroxide. Worse, I had run out of blacklip oysters. The main problem was that the available male oysters were not quite ripe, something that you could not determine without killing the oyster to open it; and then it was too late to apologize and put it back to mature further.

In September, it was time to attempt to spawn the precious goldlips from Samarai. They were all quite large, 20 or more centimetres in length and it was anguishing to have to sacrifice them. The eggs appeared ripe and trials were done in two strengths of seawater with and without various concentrations of ammonium hydroxide.

Active sperm turned out to be the problem again, with only one of the ammonium concentrations causing much movement. However, there was no fertilization. A sad day. Equally sad was a second trial two months later. My notebook simply says “14 Nov. Similar exp. Same results.”

In November, I also had more blacklips on hand to attempt another spawning trial. This time I used two strengths of seawater and four concentrations of ammonium hydroxide separately on the eggs and sperm. The male may not have been sufficiently mature; the sperm moved slowly at best, although they were capable of spinning the eggs around—like seals spinning balls on their noses. None of the combinations resulted in fertilization. Another trial in December using different seawater strengths and the same ammonium concentrations also failed to result in fertilization. A third trial the same month used shorter immersion times in stronger ammonium in two strengths of seawater, but the ammonium, while making the sperm very active, deformed the eggs.

These were disappointing experiments. I took great care in washing the eggs gently in well filtered seawater; made sure temperature was just right; collected fresh seawater, ensured there was no contact with any metals; used distilled water for diluting solutions; and replaced the ammonium hydroxide solution with fresh seawater after the first hour, lest it become a poison itself.

At the Japanese pearl farm, I discussed with Dr Wada some of the problems in fertilizing and rearing goldlips. He had managed to get some individuals to the spat stage, which was quite an achievement. But with all his experience and resources, I could see there was a long way to go. It was more than 20 years later before goldlip pearl oysters could be reared efficiently on a routine basis. And the spat settled on all sorts of plastic-based collectors.

Deaths and Detectives

Deaths, payback, mice and men

The pivotal event of this story, the deaths of three children in April 1972, took place in a village 80 kilometres east of Port Moresby. At first, the news was confusing. Local hospitals in the vicinity of Port Moresby had been filling up for several weeks with people suffering from symptoms not seen before in the area: tingling sensation in the lips, hyperactivity, ataxia, and mild convulsion; and paralysis of the respiratory mechanism. In all, there were seven distinct episodes covering several adjacent villages during March to July 1972.

After the deaths, village residents began looking for "payback," that is, revenge. This meant killing the perpetrators or extracting "blood" money from them. When doctors arrived in the village of the dead children to investigate the source of poisonings, they found the villagers on a war footing, preparing for battle against residents of the next village, whom they suspected of having poisoned the water in their well. Residents of the other villages were blaming the government for contaminating their wells with DDT, which was being sprayed in an effort to kill mosquitoes to reduce the widespread incidence of malaria in the area. There were angry, noisy confrontations between different villages and between villagers and government officers.

No one could provide an answer that would placate the villagers; the illnesses had no precedent. Fortunately, the villagers were persuaded to wait for the government agencies to find the cause before they slaughtered one another indiscriminately. Thus, the prospect of bloodshed remained a threat between the villagers; an answer would have to be found fast. The well water was quickly determined to be quite clean and devoid of pesticide.

The patients' symptoms were not of simple poisoning. Shellfish were the main component of the victims' last meal and Health

Department doctors determined that all who died or became ill ate shellfish. But then again, shellfish were always a prominent part of their diet. Some had eaten oysters and others had eaten various kinds of clams. Some ate them fresh; others boiled them first.

There were few possible causes of the deaths, if indeed they were from eating shellfish: shellfish poisoning is either an allergic response, unlikely to occur simultaneously in a large group of people; gastrointestinal, from unsanitary conditions and with easily recognizable symptoms of nausea and diarrhoea; or paralytic shellfish poisoning, caused by the shellfish feeding on a kind of algae in the plankton that is harmless to the shellfish but potentially fatal to humans. (Much later, in 1987, another form of neurotoxic shellfish poisoning, called amnesic—because patients suffered from memory loss—was found in eastern Canada, also derived from algae in the plankton.)

A call for help in solving the mystery arrived at the Kanudi station. As the mollusc “expert”, I joined a team of chemists—Mal Price and Greg Worth—and a neurosurgeon, Frank Rhodes.

One of the joys of working in the territory was the speed at which decisions could be made and action taken. The bureaucratic red tape one normally associates with any government-led undertaking was simply absent. Our team was not appointed, let alone given terms of reference or a chain of command. The four of us had a preliminary meeting, at which we concluded that the most probable cause of illness was paralytic shellfish poisoning and discussed how we could verify or discount that conclusion.

We felt like, indeed we were, detectives. The clues to the mystery might seem obvious now, but in the still-remote tropics in the early 1970s, they were as obscure as any faced by Sherlock Holmes. Immediately after the meeting, Frank called for all the patient case histories, the chemists sent for mice and I called for a helicopter.

Frank wrote a clinical description of the cases for the Papua New Guinea Medical Journal. He suggested the name Ataxic Shellfish poisoning. The term paralytic shellfish poisoning, or PSP, had been around for some time, but, like the organism that caused it in Papua New Guinea, it was more or less unknown in the tropical Pacific. The symptoms are those of nervous disorder, such as forms of paralysis; at worst the breathing mechanism fails and the patient dies. Patients who survived 12 hours usually recover, as did all the adults who were hospitalized with the symptoms.

According to the Association of Official Analytical Chemists, the standard method of measuring PSP at the time was to inject finely ground solutions of tissues from the shellfish (and later we extended this to the plankton) into live mice, a practice I might add that has since given way to chemical analyses.

The procedure called for using 21 individual 20-gram mice of a certain strain for each test, but beggars cannot be choosers as they say. The chemists were lucky enough to find some mice being held for other clinical purposes in the Health Department, which actually had a breeding program of mice for "bioassay" tests, and several cagefuls were dispatched to the Agriculture Department's chemistry lab. Even so, they could use only 6-10 mice for each test. Additionally, there was no standard toxin available to use as a reference that would enable us to quantify the strength of any toxin.

Nevertheless, the results were quite conclusive. Toxicity was rated on an arbitrary three point scale. A mean death time of mice of less than 7 minutes was regarded as toxic; death times between 7 and 20 minutes were regarded as representing mild toxicity; while mice surviving longer than 20 minutes did not subsequently die. Shellfish taken from meal leftovers in the affected villages, either raw or boiled, proved to be toxic or mildly toxic in all cases. In most cases, the mice died in less than one minute—it was a powerful poison!

The search was extended to other shellfish picked from the shoreline and the toxin was found to be confined to bivalve shellfish, like clams and oysters. Some of them, like the blood cockle, lost their toxin and became safe to eat about a month after the red tides disappeared, while others, like—unfortunately—the edible rock oyster, remained mildly toxic for at least four months.

Meanwhile, I was aloft in the yellow dragonfly helicopter. If PSP was the answer to the poisonings, it was caused by a red tide, similar to that said to have been the first plague in Moses Egypt. In this case, it was evidently a variety that does not kill fish as did the plague. There were no signs or reports of patches of dead fish. But there ought to be discoloured water caused by concentrations, blooms, of a suspect planktonic organism dense enough to be seen from the air, which would correspond, according to the scientific literature, with concentrations high enough to cause the death of persons eating shellfish from places where the blooms occurred.

Sure enough, I began to spot patches right outside Moresby harbour and these continued all the way along the 80-kilometer stretch of coast where the affected villages lay. Being new to helicopters of any size, I was absolutely thrilled and heedless of the danger as we clattered low over stretches of beach and up over headlands between them; children and adults waving as we passed.

The investigating team's report, which appeared in Pacific Science journal in 1975, stated that "40 kilometers of the coastline were tinged faintly brown…interspersed with orange-brown streaks from 0.1 to more than 1.0 kilometers long and 10 to 50 meters wide, running generally parallel and close to the coast."

We had our red tide but it still could have been a harmless type, not related to the poisonings. The red tide that gave the Red Sea its name, for example, is a harmless algal species and red tides of the same algae are common in the tropical Pacific.

The next step was to take water samples. Rushing straight from the helicopter, I arranged to rent a speedboat and driver, grabbed some collecting gear and headed for the site. The trip was awful to say the least. The daily monsoonal wind had come up and generated a sickening swell. It caused the speedboat to leap and plunge and shudder as we pounded our way eastward to the village. It was a nightmare of a ride. And when we arrived in the area, red tide was nowhere to be found. The view from the sea surface was of the next few crests and the swell was probably dispersing any blooms. Nevertheless, I took some seawater samples and when I examined them under a microscope back at Kanudi, I found abnormally high numbers of one single-cell algal species.

This was promising but I had to get samples from a visible red tide to make sure it was composed of the same tiny cells I was now peering at, swimming around the microscope slide, heedless of my giant eye above them.

In the current weather, finding red tides from surface vessels was going to be a needle in a haystack business. Aerial support would be necessary, so why not take samples using the helicopter and avoid the surface vessels altogether?

Early next day, I was in the dragonfly hovering over a dense red tide near outside Port Moresby Harbour. For sampling, I had a Nansen bottle. This was the standard tool for plankton sampling. It was a heavy tube of brass and was lowered down a wire while open at both ends. When it reached the desired depth, a heavy messenger weight was sent down the wire that tripped a spring that closed both ends and secured exactly one litre of seawater. In the laboratory, one filtered off all the seawater and identified and counted the organisms left behind.

Both the pilot and I were rather nervous about balancing the helicopter a few meters above the sea in one spot while the sampling was done. He was sweating at the controls shouting at me over the noise of the whirring blades to hurry. I had to lean out into space with one foot hooked behind the seat, dangling the heavy equipment over the red tide. In this awkward position I managed to take a few samples before the pilot became overwrought, and suddenly took us almost violently upward, shouting “That’s enough”.

Flying saucers and aliens

Placing just a drop of the precious helicopter samples on a slide under a high-power microscope, I was amazed to see huge numbers of orange-brown coloured algae actively swimming around the field of view, mostly as single cells but some in chains of up to eight cells. It was a planktonic red tide all right, the same beast I captured from the speedboat. I estimated there would have been more than half a million cells per litre of seawater.

But what were they? Each cell resembled a pair of lumpy flying saucers joined face to face on their flat sides, slightly separated by a narrower girdle from which a long hair could sometimes be seen vibrating at high speed. Photos of known red tide organisms in the available books and reports did not quite resemble it, although it was clearly closely related to known producers of paralytic shellfish toxin.

I rushed some of the live material over to the chemists' laboratory in Konedobu to see how the mice would react to a direct injection of this organism. We watched as the hapless mice were injected and replaced in their cages. The seconds passed and then a minute and then five minutes. Nothing happened. The mice recovered from the indignity of being injected and were quietly sniffing around their new "quarters".

This was a major setback. I had to think about that over the next few days. If these algae were not the killers we were back to square one in the puzzle. Yet, there was nowhere left to look unless all the other clues were wrong as well.

Small as they were, about six hundredths of a millimetre in diameter, these red tide algae had a rugged-looking shell. From my undergraduate biology lectures, I remembered that shellfish, most of which eat whatever small planktonic algae come within reach, suck them in through their gills; the algae are captured on mucous on the shellfish's gills and passed along to the stomach via a kind of mortar and pestle apparatus, the pestle being called the crystalline style.

This handy apparatus breaks up the plankton for digestion. Maybe we needed to simulate this pestle and mortar action to release the poison in the cells.

Later, I had reason to believe that the algae were not broken up inside the shellfish after all. At the moment though, it was becoming clear that I needed to test the internal contents of our red tide organism.

The chemistry lab had a sonic disintegrator, a device that sounded like a ray gun from an old sci-fi movie but was really a simple metal cylinder that produced sound waves to break up tough matter placed inside it, like the armour plating on these algae. I was amazed that the territory was in possession of such "modern" equipment, and drove at high speed to the laboratory with some of the sample material, a portable aerator humming away to keep the water oxygenated. There was no time to lose, as the cells could not live long in their concentrated state. Of course, I hid my emotions as I nonchalantly tipped in some of the helicopter's sample into the cylinder. We blasted a sample of red tide cells with the machine, which, left us with an orange liquid and, the microscope revealed, a mass of broken pieces of shell. The liquid was injected into the hapless mice and they died—very, very rapidly. We had our culprit.

Subsamples of the red tide were preserved in small vials, sealed, and sent to plankton experts. Over the following weeks, their findings arrived. They were unanimous: the killer was the dinoflagellate alga *Pyrodinium bahamense*. Dinoflagellate means big tail, there are two of them—they function as propulsions units—and it was the larger of these that I saw whirring in the first samples.

Later, as a finale to the work in the territory, I assembled two subsets of more than 80 plankton samples forming a temporal sequence over an 18-month period, from many locations around the territory that I had sampled, and packed them in foam boxes. One was sent to John Dodge in London. John specialized in dinoflagellates and from the collection of samples I sent him from around the territory, he found 107 kinds of dinoflagellates, including species that in concentrated form, that is, red tides, would be poisonous to fish; while others would be poisonous to adults eating shellfish. Fortunately, there was no sign of them becoming a nuisance.

I was astounded at the dinoflagellate diversity but John pointed out that had a finer-mesh net been used, say 10-20 microns instead of 48 microns that I used, and had special preservatives for naked dinoflagellates—species without a shell—many more would have been found. But a finer mesh net would have clogged too quickly for the kind of field work I was doing, which was only to paint a broad brush picture of the plankton kaleidoscope.

I looked for more details in the scientific literature. To my horror, I learned that this positively identified organism did not belong in New Guinea! It should not have been anywhere near the western Pacific Ocean at all. *Pyrodinium*, the taxonomic books all said, lived in the tropical and subtropical parts of the North Atlantic Ocean, Caribbean Sea, eastern Pacific Ocean, Red Sea and Persian Gulf.

Now I had more questions than answers. The organism was well known for persistent bioluminescent, or phosphorescent, displays and blooms in the Bahamas (where it was first discovered; hence the species name *bahamense*), Jamaica, and Puerto Rico; it was an asset for tourism. In fact, there has been concern about *losing Pyrodinium* by opening the entrances of the narrow bioluminescent bays for navigation purposes or by polluting them. There was no mention of it being poisonous.

The bioluminescence—the cells flash like fireflies when disturbed, but of course on a microscopic scale—is said to act like a flashbulb going off in the eyes of tiny predators and perhaps even alerting predators of those tiny predators to their presence, a burglar alarm effect.

It was later in the year when I read the old colonial reports of poisonous shellfish when there was phosphorescence in the lagoon waters in the Trobriand Islands, and several more months before I took plankton samples there. They did not show any *Pyrodinium*, but it seemed more than coincidental. Perhaps in these islands, which are to the north of the main island (Port Moresby is on the south side of the main island), a similar poisoning event took place decades ago and it was quickly associated with the evening glow in the lagoon waters. There is no similar shallow lagoon along the Moresby coast.

The major question in my mind was: where did *Pyrodinium* in the territory come from? I scanned all the literature I could find. Until at least the early 1960s, it had not been found in plankton surveys in Papua New Guinea waters, including Port Moresby; nor in tropical Australian waters to the south, even in surveys in the Gulf of Carpentaria, Arafura Sea, and Torres Strait, which were all close by. The nearest waters where it was a known resident were, to the north, the Red Sea and Persian Gulf and to the east, the American coast. That conundrum was to sit, unanswered, at the back of my mind for several years.

Meanwhile, I made weekly flights in a small plane over the next few months along the affected coastline, at the same time of day on each trip. The red tides waxed and waned and toward the end of the "season" turned up in Port Moresby Harbour. This was alarming because many villagers regularly gleaned seafood along the shores. Health warnings on posters had earlier been sent out in several languages with photos of common shellfish to avoid, based on our mice test results. With *Pyrodinium* in the harbour, the effort was redoubled to avoid a potential disaster. There *were* no further poisonings fortunately. Still, I remained uneasy; it was difficult to imagine total avoidance of these shellfish among thousands of poor villagers. Was there another factor we had missed?

The algae disappeared abruptly when the rainy season ended in early June 1972, and my weekly flights were reduced to fortnightly up to December. I kept a "permanent" plankton sampling station in Port Moresby harbour where I monitored the plankton for

Pyrodinium on a fortnightly basis by towing out fine-meshed net around the surface waters.

A false alarm on one post-season flight had me back in the dreadful speedboat in August, and this time we found the cause. My notes said:

> "Open speedboat head on into the southeasterly wind 50 miles (and 50 miles back), starting at 5 am. I'm sunburnt, windburnt, and bloody near got stung by sea wasps, which happened to be among the red tide things (which turned out on this occasion to be salps with a red pigment inside), and which I found out by leaping in amongst them…"

Pyrodinium remained a very minor component of the plankton or was absent until the next rainy season in February 1973. In both 1973 and 1974, Port Moresby harbour hosted quite strong blooms of *Pyrodinium* during the rainy season, which was roughly February to May. From the pearl farm in Fairfax Harbour, I learned that there was also one during the 1971 rainy season but apparently none in the previous two years (1969 and 1970) for which the farm had kept records.

Yet only one, that in 1972, caused deaths from eating toxic shellfish. Almost miraculously, the workers at the pearl farm in Port Moresby Harbour always ate without ill effects the pearl oysters that were sacrificed or died during culture operations, even during the deadly 1972 outbreak.

Our shellfish poisoning team discovered, by separating the parts of the shellfish before grinding and extracting, that the poison was not spread through all their tissues but was primarily in their digestive organs; their muscle tissue was quite harmless. The poison content was the same in fresh and cooked tissues. The villagers poisoned in the 1972 red tides ate all the tissues either boiled or fresh. On questioning the pearl farm workers again, we learned that they liked to eat the pearl oyster muscle only, not the other tissues—an extremely fortunate choice!

It is probable in hindsight that *Pyrodinium* was more common than the surface samples implied because of the way the individual cells moved up and down the water column during the day, which is known as their vertical migration. During the red tide “season”, blooms that were visible—that is, rose to the surface—early in the morning would stay on the surface until late afternoon, but if they did not appear until late morning, they left the surface early in the afternoon. This behaviour seemed to have little relationship with the amount of sunlight or rain.

To put this on a more scientific footing, I took plankton samples at the surface and at around 5 meters every two hours for 24 hours. These were preserved for later analysis. The samples revealed that *Pyrodinium* cells were at a minimum in the surface waters from around dusk until midnight. Thereafter they gradually rose until after dawn, were probably distributed more or less evenly though the upper five meters during the day, and began to sink in the late afternoon.

I became intrigued by the behaviour of these tiny cells that could be so dangerous. Investigating the biology and ecology of *Pyrodinium* soon overtook the oyster and pearl oyster studies as I began to devise laboratory experiments to shed more light on their life cycle.

In the samples taken every four hours over a 24-hour period, I could see the cells dividing, which they did more often during mid-morning to mid-afternoon, with a minimum at 2 am. At most, nearly a quarter of the cells were dividing at any one time, which I concluded meant a generation time of around 4 days.

I wondered about the implications of a generation time as long as that on red tide formation. What I had seen on occasions was a thin band of *Pyrodinium* in the water column on one day and a thick band on the next. Where did they all come from? They were more dispersed through the water column in thin band days but when there was no band at all, their numbers seemed too low to cause a much denser thick band in short order. The answer, I was to learn, lay in their swimming speed as well as in their capacity to divide more rapidly than I expected.

I was fortunate in finding John Caley, an Australian microbiologist who instantly became enthusiastic about culturing red tide. John was one of those rare lateral thinkers who look at all the possibilities, however improbable. I would bring into his laboratory fresh plankton samples from the harbour and we would attempt to grow them in various chemicals.

John came up with a very simple and relatively successful culture medium for *Pyrodinium*, the addition of a weak solution of yeast that had been autolyzed by the sonic disintegrator, the same process we used to split open *Pyrodinium* cells themselves. The cultures were short lived but long enough to learn that when they were constantly illuminated, the *Pyrodinium* were dividing every 9 hours, ten times faster than what seemed to be happening in the field.

One the one hand, my estimates were based on observations made when there were no visible red tides, that is, probably not in ideal conditions for *Pyrodinium* to multiply. Nine hours, on the other hand, might be an artificial maximum (or it might not; my 60 watt globe was not comparable to the sun!). It did appear that when conditions are ideal, the cells can divide fairly rapidly—nearly 3 times a day in my cultures, meaning that one cell today may become about 7-8 cells tomorrow; maybe 60 the day after.

Pyrodinium, like nearly all dinoflagellates, can swim well using its two big tails. This would help in forming blooms and keeping them in one place as well. *Pyrodinium*'s apparent swimming speed as measured by downward movement of bands in the harbour over time was between half and more than one meter per hour, quite adequate to explain their appearance and disappearance in the turbid harbour waters.

But these swimming speeds were for the whole band; individual cells might be slower or faster. In the laboratory, I put small numbers in a perspex (plexiglass) tube and waited until they formed a thin band at the top. When I switched on a 60 watt light underneath the tube, they swam down toward it immediately. The little orange band averaged 0.60 meters per hour, still quite impressive.

The apparatus gave me an idea for finding out their salinity preferences or limits. I placed another small batch of live *Pyrodinium* in a similar tube containing filtered seawater of salinity 36.5 (parts per thousand, or ppt) lit from above with a 20 watt fluorescent light. The sides were blackened to minimize ambient light. The cells responded by forming a clear orange band 1.5 centimetres thick at the water surface. Next, I withdrew some seawater from below the band with a siphon and gently replaced it with distilled freshwater on the surface. The cells were disturbed but soon reformed their band, now lower in the water column. Water samples were then taken from just above, below and in the middle of the "red tide" band and the salinity of the samples measured. It was a fun experiment and would provide some important information.

The experiment was repeated several times with fresh *Pyrodinium* recruits. Despite the temptation of the light above, they were unable to swim up into salinities less than 26 ppt; the salinity in the mid-points of their bands was 28.6 to 31.5 ppt. In Port Moresby Harbour, bands were found in salinities of 28.5-36.8 ppt, the latter being as salty as the harbour got.

Now I knew how little salt the cells liked in their surroundings, but how much salt would they prefer? I let some seawater evaporate, placed it in the tube and again carefully added some sterile freshwater on top. Active cells were added and the light was switched on, this time beneath the blackened-sided tube (because the more dense seawater naturally sinks to the bottom). The cells busily swam down until they formed a band at nearly 41 ppt.

In an open sea, salinity rarely goes above 38 ppt. There is only one area in the world where the average salinity is higher, the Red Sea and the Persian or Arabian Gulf, at 40 ppt. These places were indeed home to *Pyrodinium*.

I pored over the literature again. Could there be a connection between the Persian Gulf and red tides in Papua New Guinea? Plankton taxonomists were already inclined to think that *Pyrodinium* in the Persian Gulf-Red Sea area and those in tropical America were different subspecies because the shells of *Pyrodinium* in the Americas were taller and rounder than the ones in the Persian Gulf. The Papua New Guinea *Pyrodinium* fitted the description of the Persian Gulf subspecies. In the wake of my work, the apparent nontoxic feature of the American "subspecies" added a little support to the separation of the two subspecies but neither of them was known to be poisonous. And there were to be unwelcome surprises in that regard too.

There is a lot of tropical water between the Persian Gulf and the South Pacific. Why was *Pyrodinium* not turning up in plankton surveys in between? It was as if the organism had leap-frogged over the Indian Ocean entirely.

One clue lay in the oceanic traffic in the past two centuries between European countries and their colonies or protectorates. The Suez Canal opened in late 1869, saving vessels from Europe more than 6,000 kilometres on their journey to Pacific Asia and the Pacific islands. No longer did they have to travel down the coast of Africa and around Cape Horn.

The Suez Canal rapidly boosted trade between Europe and tropical countries—both on the Asian mainland and island nations—in the nexus of the Indian Ocean and South Pacific. Copra (dried coconut), coconut oil, beche de mer, and tortoise shell were some of the main products that filled their holds in the western South Pacific islands. Papua New Guinea was the natural main focus of attention for traders. Its land area is greater than all the other Pacific islands combined and had the best developed and safest ports dotted around the islands.

Trading vessels belonging to the Dutch and British East India companies and in turn the German New Guinea Company sailed through the Suez Canal. They were the missing physical connection between the Red Sea and the territory. Strange as it appears, *Pyrodinium* probably also travelled in these same boats.

Those European trading vessels were not carrying heavy cargo on their outward journey. They would have added water as ballast on leaving their home port, the water ballast itself a relatively new idea; prior to the latter half of the 1800s, most ballast was of solid material. The Suez Canal was about 8 meters deep until the 1950s when deepening began. Some early trading vessels would have discharged ballast water to go through the Suez Canal, and refilled their ballast tanks in the Red Sea. This water would then have all been released in the trading ports, which, in the tropical Pacific, were mainly in Papua New Guinea.

But how could the algae survive, locked in dark, airless holds for the weeks of the journey? I found the answer in another aspect of *Pyrodinium*'s behaviour. One of its survival mechanisms is to shed its swimming tails and form a tough cyst when conditions are not favourable; the cell is then said to be dormant. If the ocean crossing was not to their liking, the swimming cells in the ballast water could "close shop" and form these protective cysts until their release into suitable seawater conditions. The cysts can keep them alive for years or decades, and maybe even centuries if necessary.

A common feature of successful alien species, as I was coming to believe of *Pyrodinium*, is their ability to thrive better than the local species, which have all adapted to each other and live in some sort of uneasy balance. A new species on the block can take them by surprise, have no predators (yet), and easily dominate the neighbourhood.

Yet, this could not be the whole answer. Otherwise, it would indeed have dominated the waters around Port Moresby, for instance, for a full century.

Now we are coming to a crucial argument. Why did those New Guinea villagers eat what turned out to be poisonous shellfish, when they had so much knowledge of their environment and of the friendly and dangerous animals and plants around them gained over 45,000 years?

The answer, of course, is that they did not know that such shellfish could suddenly become poisonous. Generation after generation had been eating them probably throughout the entire 45,000 years since the first arrivals sat by the shoreline to explore the pickings. Coastal lore on safe seafood would be well entrenched to say the least!

This to me was probably the best evidence of past absence of poisonous red tides in the area.

And if not, why not? Why did not poisonous episodes occur there before 1972? This wasn't simply an academic question. If *Pyrodinium* was leading a cryptic lifestyle in the past, its behaviour could well have a bearing on outbreaks of red tides or paralytic shellfish poisonings in the future.

I think the oceanographers could be forgiven for not finding *Pyrodinium* in previous surveys in the western Pacific. I found it absent from surface samples even Port Moresby Harbour for weeks at a time, while present at concentrations of up to several million per litre in surface seawater at other times.

There was the possibility or probability that the *Pyrodinium* population was spending some or all of its time on the bottom of bays and harbours, out of reach of plankton nets. Waiting.

If so, what made the algae suddenly wake up, start blooming and poison local human residents?

It was over a decade later before I had a partial answer to that intriguing and important question. First, there was an outbreak, similar to that near Port Moresby, on the west side of Borneo in 1976 and then, the clinching clue, the first recorded outbreak in the Philippines in 1983.

However, we are still in New Guinea and by now it was time to leave not just the unanswered questions but the country itself.

Home and Away Again

Much as my research in the territory was as fascinating as it was important, life for a family was becoming increasingly unsafe during those two critical years before the territory became self governing. In October 1972, I wrote to my friend Albert in Canberra that Port Moresby was already

> "thick with horrible rumours, occasionally denied in the press, of a new currency soon to be flooded into the country. A customs officer, says the grapevine, who was told not to open certain boxes, is said to have peeked inside and actually seen the new bills. So everyone we know, truly, has sent their cash out of the country. I've taken the easy way. Mine's already spent. But there is worse to come. A Minister has denied the idea that they are contemplating a 10% export duty on everything the expatriates take out of the country. Rumours persist and friends from a wide variety of departments hear the same story."

Looking back, the presence of a new currency in 1972 seems unlikely. The kina was not put into circulation to replace the Australian dollar until 1975. But it was a good story to fuel the rumour mill at the bars of expatriate clubhouses around the country.

Meanwhile, in Australia, the Labour Party came to power in December 1972 and immediately pushed the Papua New Guinea House of Assembly toward early independence, not so much for its own sake as to remove from Australia's image that of colonial master. Self-government was set for December 1973, with independence probably before 1976.

These political moves trickled down to the Papua New Guinea population in a broth of suspicion and intrigue. For locals and expatriates alike the situation became one of even greater rumour mongering. Most expatriates felt the territory was not ready for self-government and locals believed that expatriates were fomenting negative views on the issue.

By the end of 1972 I wrote to the Secretary of the Department of Interior in Canberra, the agency in charge of accommodation there, to ask:

> "…as a matter of some urgency if it is possible for my family to precede me to Canberra and take up a Government house. I will be returning to Canberra in November 1973, but would like them to leave as soon as possible.
>
> One of the major reasons for my seeking your approval in this matter is the impossibility of getting schooling for my daughter and I am often called away from Port Moresby where my family is staying, and you may be aware of the turbulent social conditions here."

The request not even answered.

"Turbulent social conditions" was an understatement. Robberies were rife and becoming bolder. There were intertribal riots at football matches and tribal gangs chasing each other through the streets; there were a few slayings of expatriates. At the end of January 1973, after only a year in the territory, I wrote to Albert that there was a "virtual evacuation going on" as a result of the announcement that the territory would become self governing on 1 December 1973 as a step toward complete independence, possibly after a further year.

Rumour, if not fact, had it that the Chinese were migrating en masse to Australia; two orders of Australian nuns had been ordered home, and there was a net emigration of hundreds of expats each week. And rumour around Moresby suburbia was that on 1 December, the locals, generally the houseboys, would take over all the housing and "get rid" of the expatriate residents. "Getting rid of" was sometimes interpreted as killing any expatriates silly enough to stay after that date.

Looking at our gentle houseboy, it was hard to envisage him shooing us out of the house or, as some would foresee, killing us.

Nevertheless, in January 1973, I booked our return flight south for mid-November, fortuitously the official end of the secondment, taking vacation time into account. The flight was already half full!

One year into our stay, attacks and robberies were so rife that we had to take extraordinary precautions. In March 1973, in a letter to Albert I mentioned that

> "Nothing is really newsworthy in PNG other than the usual, but more frequent, rapes and burglaries. The police are selling and licensing $4 gas pistols for expatriate protection!"
>
> We did buy a gas pistol and my wife took delight in cleaning it every so often, sitting on the front steps in full view of passing locals. Maybe it helped keep out the burglars. It could, of course, have meant that potential burglars felt they would have to 'subdue' us before we had a chance to use the gas."

At the end of April 1973, I wrote to the Secretary of the Department of Primary Industry in Canberra about where I might expect to work on return in November. The reply, dated a month later, was one of those bureaucratic efforts that are understandable only to fellow government employees, which hint at satisfaction but give nothing away.

> "You should write to the Public Service Board advising the date you intend to return to the Commonwealth Public Service and advise your present Department of your intention to resign at the end of business on the previous day. The Board will then ask this Department whether you can be placed."

That wasn’t exactly comforting, but the anonymous writer weakened a little after that:

> “The Fisheries Division would be pleased to have you return but this will be subject to a suitable vacancy being available at the time you take up duty.”

But he/she returned to matters at hand in the remaining paragraphs, which did have a comforting ring in their disembodied Victorian precision:

> “Your period of service in PNG will count for incremental purposes. Your salary at Class 6 level has therefore reached the maximum at $8230 p.a.; the recent national wage adjustment is to be added to this.
>
> Hotel accommodation at the Hotel Acton could be arranged for you and your family when you return. The current charge for full board per adult is $26.10 per week. As you were previously receiving Regulation 97 allowance this will continue to be paid to you until you either move into your own or a government home or receive your second offer of a government house”.

The Office of the Public Service Board took six weeks to reply to my subsequent query to them:

> “Dear Sir, Reference is made to your letter of 14 June 1973 concerning your re-integration into the Commonwealth Service when your present contract with the PNG Public service expires in November 1973.
>
> The usual practice associated with the re-integration of officers returning from PNG is for appointment to be effected with their former department. In accordance with that practice, this office has requested that Department of Primary Industry initiate action to obtain a suitable position

> to which you may be appointed. You will be advised of the outcome of this request in due course."

These letters were jewels. Although they simply sent me in circles, I sensed the motherly arm of Canberra reaching out, even if it were a robotic arm.

Nevertheless, I wrote to a few universities over the following months with the idea of doing a doctoral degree based on the research I was presently doing. The University of Papua New Guinea, while not world class, was the ideal location, but their reply was negative: "There has been a tightening up of rules here with a view to discourage non-resident expatriate students".

In September 1973, I was surprised to receive a letter from the Papua New Guinea Chief Minister, Michael Somare, asking me to continue working there and guaranteeing employment for at least another three years:

> "This decision to invite you to continue your service to this country at a time when localization is so important to us has not been taken lightly. It results from careful inquiry by your department head in consultation with Ministers and the Public Service Board. Your personal past contribution to the development of this country has been particularly taken into account".

But it was too late. There was no question about leaving at the end of the two-year contract. Living conditions for my family continued to worsen; they had never been good in terms of health, while in the latter months, physical danger appeared to be mounting and, whether real or perceived, added to the psychological burden of coping.

With our furniture packed quite competently by the local moving company, we gladly left our shoebox of two years, and spent a last night in the city's only big hotel. As this account was being written in 2011, Asian Development Bank staff with whom the author is acquainted, stay in the same hotel and are forbidden to leave it without guards. They are escorted to their office a few hundred meters along the main street and after the meetings are escorted back! The danger of attack and mugging by local “rascals” in the main street was now that great.

We arrived in Canberra in late November 1973 and within a week, as Papua New Guinea took its momentous step into self-government, I had my first Christmas present, a parking infringement notice for forgetting to display the parking voucher. It was, in its own way, my welcome home.

My mind was still full of the excitement, adventure, friendships and unfinished work in New Guinea. I realized that I had to go back and try to solve the riddle of *Pyrodinium*. I sent an application for a reprise before we had even unpacked our belongings.

Getting back, at least for a brief working visit, turned out to be relatively easy. I outlined to my Canberra superiors a plan to be there in March and April 1974, which would be in the middle of the next red tide season. The plan nearly went awry. The Assistant Director for Research and Surveys in Papua New Guinea, wrote to me in January 1974:

> “by the time staff got around to looking at your extension of contract they had already closed your file and got you off the book, so an extension of contract is not feasible.
>
> However, I have now made a formal approach to the Australian Staff Assistance Group, which was recently set up in Canberra to handle Australian staff aid generally to overseas countries and I am reasonably confident that we will be able to get you back here through this group”.

His confidence that I could return to continue the red tide work, which was after all, an important health matter, was well placed. The Colombo Plan—Australia’s first halting step, beginning in the 1950s, to relax the White Australian Policy by, *inter alia*, sponsoring

Asian students to study in Australia—was invoked to send me back to Port Moresby as an aid expert for two months.

Jon Peters was still in Kanudi and, as he wrote, had things more or less in order:

> "All the glass tanks are functioning and the 10,000 gallon fibreglass tank is in operation, so things are sweet for March…Your ex-assistants still try to do the weekly Napa Napa [plankton sampling] run, but there has been a boat shortage since the aluminium dinghy and 20 hp Johnson were stolen."

My planned activities were to be in the laboratory and in Port Moresby Harbour. There as one notable exception, as explained in the subsequent report of the two-month study. "

> "Field work was carried out in Port Moresby Harbour (where red tides were frequent during my stay) with the exception of a voyage to Milne Bay for the purpose of collecting plankton from the open sea to compare with the harbour samples. The navy, via the Papua New Guinea Defence Force, kindly allowed me to embark on the 'Samarai' during its return to Manus from a refit".

The Samarai was an Australian Navy patrol boat that had become property of the country following self-government in December 1973, while retaining an Australian captain and several senior crew. I wanted to see if *Pyrodinium* was a coastal beast or either tolerated oceanic conditions or came into coastal waters from the open sea each season. The Samarai's route was to run down the east coast, slip through the China Strait and turn north for the Manus group. We set out one afternoon. It was thrilling to be high up on the bridge as the 30-meter boat began to meet the oceanic swells and slice through them, but soon it was like being on a bucking horse. The plan was to head more or less into the rising swell and later turn northeast to keep the swell on the starboard beam.

Sampling proved to be a juggling and balancing act. The vessel could not completely stop because it would turn side on to the swell, which was getting impressively bigger as we headed further southward, and the boat could possibly roll like a cork. Still, it came close to that situation as I hung onto the rear deck with seasoned sailors hanging onto railings watching me attempting to get the net over the back of their boat without dropping it onto the propellers. I got two samples before the captain advised against any further "stopping".

Relieved, I made my way back to the bridge and rode the bucking navy horse, making up a tune and lyrics to keep my mind off my heaving stomach as we lunged into the Arafura Sea in the darkness. The swell became higher and higher. I watched with no little misgiving the flagpole at the stem suddenly torn off when we crashed through a particularly high foaming crest. It was time to come about. Thereafter, the vessel's movements were less ferocious as pitching was replaced by rolling, but the rhythm finally made me nauseous so I went down to the bunk allocated to me and tried to finish the song, thankfully falling asleep before sickness overwhelmed me.

By morning, we were lost (!) and one engine had broken down. So much for the refit. Running at more or less half speed, we were nevertheless in sight of land and when I came on deck, the officers were trying to match the coastline with drawings in the Pilot. I didn't care about the Pilot. The distant coastline in the early morning haze held my attention as rivetingly as the island's coasts had since I first arrived in the territory and saw the shores of Port Moresby Harbour and the adjacent bays. Each bay and indentation in the territory's coastline surely had a unique story and before it a coral reef to be explored. The places beyond Moresby that I had visited had only whetted my appetite for more; perhaps they were addictive, but I knew the future held little further opportunity. Conrad, in the Heart of Darkness, hinted as much when he wrote "Watching a coast as it slips by the ship is like thinking about an enigma. There it is before you—smiling, frowning, inviting, grand, mean, insipid or savage and always mute with an air of whispering 'Come and find out'".

I was not able to take up the offer. We limped into Milne Bay; I was sent ashore with my samples with little fanfare and left to wait at Alotau airport for the next DC3 to Moresby.

Back in the Kanudi laboratory, microscopic examination showed that the samples contained no red tide organisms. But the sampling was hardly conclusive and the net had been unable to sink to any depth due to the patrol boat's movement. Yet, if *Pyrodinium* were out there, there certainly weren't many.

I needed to grow a population of *Pyrodinium* to learn more about their lifestyle and have a constant stock for experiments. There was much laboratory work to be done if I was to understand what made *Pyrodinium* suddenly multiply rapidly from being rare to several million per litre. The laboratory was modified to accommodate containers for growing them and some special chemicals were ordered that I hoped would imitate the natural nutrients in the sea. The laboratory was becoming an interesting room for visitors, if nothing else.

Batch rearing experiments in the laboratory with a variety of chemicals failed to produce blooms; but John Caley's yeast culture technique proved adequate to maintain a reasonable culture of the cells; however, we never had a population explosion or bloom as occurred in the coastal waters.

In a way, these experiments posed as many questions as they answered. We found, using a sonic disintegrator to break up the cells and the awful mouse test, that the samples were sometimes highly toxic, sometimes less toxic and sometimes not toxic at all. It was impossible to make a dose-response curve, to use the scientific vernacular, to pinpoint where the toxin resided in the *Pyrodinium* cells. That negative result, however, was in line with experience in the field—of an apparent switch from benign to toxic and back for no particular reason I could put my finger on.

The Health Department proved to be very efficient. Warnings were issued at the start of the 1973 and 1974 red tide seasons telling people to avoid eating bivalve shellfish—using pictures and local names, of course. No illnesses were reported although locals could be seen from time to time, possibly unaware of the warnings, gleaning bivalve and other shellfish in the intertidal zone in the harbour.

To complicate matters further, I found during the 1974 red tide season that absence of a red tide when viewed from the air or surface did not mean there was none! And I might never have discovered this very important aspect of *Pyrodinium* behaviour using conventional techniques.

The normal way to measure plankton abundance up and down the depths of the sea was to take a water sample at different depths, filter out the organisms and count them under a microscope. This was really tedious I knew, because I was still doing such counting of surface plankton, using the plankton net towed behind a small boat. Samples for counting are usually taken with a Nansen bottle, which as I mentioned when taking samples from the helicopter, had a closing device that could be activated at any chosen depth. The accuracy of the method depends on the depth spacing of the samples, and if there is a big swell it doesn't make much sense to take them less than two meters apart. Another way is to drop the net to the bottom with a weight and slowly haul it up, but this gives only an average count over the whole depth of the water.

My idea was simply to dive down and look at the water first hand, so to say. There were warnings in the literature that dense accumulations or blooms of red tide organisms caused nasty irritation of the skin. I was well dressed at first, but *Pyrodinium* proved harmless on the skin and finally my apparatus consisted of nothing more than swimming trunks, mask, snorkel and fins. Might I not get poisoned by accidentally ingesting some of the organisms? It was a possibility, I thought, and some of the Kanudi staff warned me against swimming in the blooms. Again, the fear proved groundless.

By snorkelling down in the harbour beside a marked drop-line, I found that the *Pyrodinium* bloom might occur as low as 10–12 meters on some days and be on the surface at the same time on other days. Not only that, the thickness of the bloom varied immensely from a meter to a mere pencil line. I took samples by simply opening a bottle in the middle of the bloom. Had I used the regular sampling method, the chances were great that I would miss even a moderate bloom, while detecting a layer of *Pyrodinium* a centimetre thick using a lowered Nansen bottle would have been highly unlikely.

This finding was bad news for shellfish consumers and health officials alike. It meant there was no reliable indicator that could be used to warn officials as to when they should place a ban on eating shellfish. After three red tide seasons, all we knew was that the red tides came only in the wet season, broadly January to May. As in other countries where similar events occurred, it was assumed that the rain brought into the coastal waters nutrients that the organism in question was able to use to grow and reproduce rapidly. Hot sunshine in between, with calm seas, allowed the organisms to accumulate at the surface to photosynthesize and reproduce and not be dispersed downward by wave action.

But that begged the question as to why the red tides were not a constant feature of the rainy season. Only in the last few field days in 1974 did I discover that the northwesterly wind that prevailed in the rainy season and its direction were equally responsible and held more sway than even full sunlight. The densest and thickest bloom I recorded in the three seasons was on the surface on a cloudy day in a rough sea, the waves having been stirred up by a late, almost unseasonal, northwesterly wind—the wind that blows waters and planktonic food in the form of nutrients from the mangrove forested inner shores of the harbour. Far from needing calm conditions, *Pyrodinium* needed the northwesterly wind to stir up its required nutrients from the inshore bottom, whether brought there initially by the rain or not. The southeasterly monsoon or even a southeasterly wind between days of northwesterlies near the end of the season, prevented a red tide from forming on those days. Winds from the south could not stir up the nutrients that *Pyrodinium* needed.

*

A search of Department of Agriculture, Stock and Fisheries files, Department of Health annual reports and old New Guinea and Papua annual reports uncovered instances of red tides and probable paralytic shellfish poisonings in the past. Over 7,000 poisonings a year occur in New Guinea—the northern half of the territory—each year alone. Details were rarely reported. The earliest recorded probable case was in 1927 while the first recorded red tide was in 1961. Over the 18 years to 1973, there were 13 separate red tide outbreaks. Poisonings from these scattered and sporadic occurrences included 10 known deaths and 160 treated illnesses.

The question remained as to why there were not regular poisonings each year when red tides were present, especially in Port Moresby where there was no tradition of avoiding shellfish at any time and people even continued to eat them despite or in ignorance of Health Department warnings.

One clue to the erratic nature of *Pyrodinium*'s toxicity was ecdysis—the shedding of its suit of armour. My previous experiments, in which we looked for poison in the cells by blasting off the armour with ultrasound, were inconclusive in this regard. But in the wild, there must be a natural purpose for shedding the armour.

I noticed that if red tide cells were collected by dipping a bottle in the bloom, such as to count the number cells in a given volume, they happily swum about under the microscope, often in a state of division, forming chains up to 8 cells long, while still capable of rapid swimming. They would do this in natural blooms where there might be up to 5 million cells in a single litre.

When they were squashed together in much greater concentrations as in a plankton net, they began to ecdyse; the more they were squashed together, or concentrated, the faster they shed their armour and more of them did so. Some would begin to fashion a new rudimentary armour after 30 minutes or so but in high concentrations it was a one-way event and the naked cells later died.

Shedding appeared to be related to stress caused by overcrowding: too many cells for the surrounding water to accommodate, a situation that one can easily imagine happening gradually at the end of a red tide season or when conditions suddenly change within a red tide season. Yet, exposing one's naked body seems hardly designed to create fear in a would-be predator or enable a cell to escape from a stressful situation at high speed. Probably, the naked cells sink down, transform themselves into the impervious cysts, and wait in the sediments on the seabed for conditions to improve.

But shedding would leave a previously armoured dinoflagellate vulnerable to being eaten by predators that were unable to digest it in its suit of armour. I wondered if, as a result of shedding, a defensive or offensive toxin were also released or became available during this process. Was paralytic shellfish poison in fact a chemical to make *Pyrodinium* distasteful to or even fatal in sufficient quantity to predators?

Bells started to ring when I reached this line of reasoning. Some time during the 1973 red tide season, I carried out a series of feeding trials to see if I could get bivalve shellfish to eat *Pyrodinium*. I could then see—with help from the chemists and some mice—how quickly the shellfish became poisonous or determine what concentration of cells would render them toxic to humans. I used shellfish of kinds known to be toxic in the 1972 red tide season: oysters, cockles, and small *Gafrarium* clams, in closed aquarium systems. However, their faeces, when they ingested *Pyrodinium*, were of intact *Pyrodinium* cells, no pieces of armour, no empty shells. For some, there were no excreted *Pyrodinium*; they did not even ingest the cells. However, I needed more sophisticated experiments and had no time to undertake them during the short, hectic for me, red tide season. Big numbers of cells as needed for such experiments were only available from the wild, that is, from and during red tide blooms.

Now, in the eight weeks available in the 1974 red tide season, which fortunately or unfortunately occurred in time for my return visit, I did not have time to repeat them. If I could have collected in time enough different shellfish to redesign feeding trials, I knew it might take weeks for the shellfish to become toxic even if they were kind enough to eat *Pyrodinium* heartily in aquaria. And you cannot tell (without some relatively sophisticated equipment not available at the time) if oysters and clams are feeding or not because they are incredibly shy; their shells open to an imperceptible degree when feeding; it need only be a matter of microns to draw in suitable food; open wider and a predator might pop in as well.

Would *Pyrodinium* poison fish? As test organisms, I decided to try small fish, fingerlings of a mullet (*Valamugil seheli*) that could be netted in the shallows of the nearby mangroves.

First, the mullet, five in each experiment, were placed in a small aquarium with a fresh batch of *Pyrodinium* from a concentrated plankton sample at about 200 million cells per litre, about 40 times the natural maximum that I observed. I made sure the water was fiercely aerated to discount the chance that cell decomposition was a factor influencing the results. The mullet began to twitch and jump in a manner described in experiments on *Gymnodinium*, a dinoflagellate like *Pyrodinium* but without armour (aha! another naked offender) that forms red tides in Florida and has a strong fish poison; it kills fish by the hundred thousand there and feeds on their bodies. On a bad red tide day the air along the Florida coast becomes thick with the poison drifting in aerosols to the extent that it sickens and sometimes kills humans; large-scale evacuation of coastal areas takes place on such occasions, all because of this microscopic naked dinoflagellate.

The mullet died in my first experiment in 48 minutes on average. Whatever was in the cells, it was certainly capable of warning off fingerling-sized fish and presumably much more so their younger larval stages and possibly other small organisms that could be potential predators of *Pyrodinium*.

The concentrated cells were filtered off and placed in fresh seawater at the same concentration. They were left to themselves for an hour and their filtrate (the seawater minus the cells) tested on the fish. This time the mullet died in 30 minutes. The cells were put back in fresh seawater again and left for 4 hours, and the filtrate this time killed the fish in 11 minutes on average. Most of the dinoflagellate's metabolic processes had finished by this time and a filtrate after 24 hours was not much more toxic, killing fish in 9 minutes on average. I had a very toxic brew. It was far in excess of what would occur in a natural bloom but perhaps not beyond the realms of possibility when a bloom "collapses" and the cells sink en masse.

Was shedding the process causing the toxicity? Most likely but to be sure, I followed the pattern of ecdysis in another concentrated brew of *Pyrodinium* and tested it from time to time, heavily aerated but this time without filtering and resuspending the cells, on mullet. The toxicity of the brew became gradually stronger in proportion to the decrease in numbers of armoured cells, until the cells died out after two days. Then the toxicity remained the same for a further three days when I ended the experiment.

When I tried the same experiment using dead washed *Pyrodinium* (armoured) cells and tried again after removing their armour with ultrasound, the mullet swam unconcerned and unaffected for the duration of the experiment. The conclusion was that the toxin was a product of the living cells, not one of decomposition or lack of oxygen. And there, the matter lay for nearly a quarter of a century.

Metastasis

For several years after leaving Papua New Guinea, I wrote to officials there at the end of the rainy season, enquiring as to whether there was any shellfish problem; the answer was always negative. By now, most villagers in the Port Moresby area have probably forgotten about shellfish poisoning, yet it is waiting out there.

My red tide investigations continued from behind a desk in Canberra. I had papers to write, information to find, and colleagues to inform and provide more clues about *Pyrodinium*.

Over the next two years, I corresponded with several journals and many peers. This correspondence put me into a network of red tide researchers, who were all interested in this new toxic beast from the wilds of the South Pacific. I was able to publish a few papers on the phenomenon. Some were reprinted in magazines. John Dodge sent progress reports on the identification of other organisms in the plankton collection. The National Meteorological Service sent data on atmospheric pressure and winds.

By 1976, I had assembled my magnum opus with all my conclusions on the life cycle of *Pyrodinium* and the causes of Papua New Guinea red tides, and optimistically sent it to a leading scientific journal, Limnology and Oceanography. I hasten to add that I first published parts of the story as I knew it with co-authors in the Papua New Guinea Agricultural Journal and in Pacific Science, a regional journal that was widely accessible and read around the tropical Pacific region; both were at the greyer end of the scientific literature spectrum.

The manuscript went off to the journal in May 1976 and, with the weight of that paper, the two years that it took to write, behind me, I was content to wipe my hands of red tide and move on to whatever Canberra had to offer.

That very same month I received a letter and parcel from Dick Beales, Director of Fisheries in Brunei Darussalam, who wanted help in understanding the first known red tide outbreak there, during January to May that year. The parcel contained samples of the organism responsible, which I quickly identified as my "old friend" *Pyrodinium*. The beast did not want to let go of me yet.

I immediately sent a large batch of relevant articles to Dick In his reply, he wrote:

> "Having read the literature you sent me, a most amazing coincidence came to light. *P. bahamense* was first described in 1906 from Waterloo Lake, Nassau, Bahamas and for six years I lived within half a mile of this lake while working for the Fisheries Division in Nassau…The fact that I should be the one to first discover an outbreak caused by this species half way around the world in Brunei is extraordinary".

These *Pyrodinium* red tides were in pockets on the western coast of Borneo and resulted in some 200 recorded poisonings and seven deaths. More outbreaks occurred in 1979-1980 and 1983, after which they became annual events up to at least 1988.

At the same time as the 1976 Borneo outbreak, a warning was issued by Philippine health authorities about red tide in southern Mindanao, which is close to northern Borneo, not far north, that is, from Brunei. I wrote to them and was told that no red tide had been sighted in the Philippines; the warning was issued in view of the Borneo outbreak, which was reported to be moving northward up the Borneo coast; it did not reach the Philippines. But, in October 1976, Elizabeth woods, working in Sabah (north of Brunei), wrote to me that the *Pyrodinium* red tide had indeed moved into the western side of that state.

Limnology and Oceanography gratifyingly gave my paper a top rating but wanted some black and white maps to show the many places mentioned in the paper. I was really unable to supply these, having no access to the drawing tools or the original large maps.

This resulted in some terse correspondence that ended in their including several hand-drawn sketches of awful quality—even using cursive writing for the names—that they made themselves, probably the first and last time the journal resorted to such unprofessional drawings.

International interest in *Pyrodinium* continued to mount over the years and in 1978, I was asked to be an “Invited Speaker” at the Second International Conference on Toxic Dinoflagellate Blooms in Florida in November that year.

In 1981, another *Pyrodinium* outbreak was reported all along the western side of Borneo and this time blooms were also discovered on the eastern side of Sabah.

By then, I had embarked on a new tropical adventure in Manila, Philippines, with an international group of scientists in the then International Center for Living Aquatic resources Management (ICLARM), albeit as their technical editor and then director of the information program. But still *Pyrodinium* was not yet finished with me!

Pyrodinium red tides reached the Philippines in 1983 (!), in a major outbreak that resulted in 278 recorded paralytic shellfish poisoning cases, including the deaths of 21 people. Someone knew about my work in Papua New Guinea and a sample of the red tide soon arrived at my Makati office. There it was, *Pyrodinium.* I smiled at first, remembering my familiarity and associations with it over the preceding 11 years; then blanched at the thought that it was following me. It had been moving northward in steps since 1972, anticipating my arrival in Manila in 1980!

The idea that I might be the cause of the Philippine red tides was not lost on local researchers, who dubbed me in half-jest the “father of red tide” in the Philippines. Mercifully, there were no more red tides for a few years and the title forgotten. But in 1987, strong red tides occurred on the coast north of Manila and in the following year, they were causing havoc in Manila Bay itself. There were visible blooms of *Pyrodinium* and deaths from poisoning as a result of eating contaminated mussels on the western side of the bay and soon after, deaths on the eastern side where there was no red tide.

Paralytic shellfish poisoning was a new phenomenon in Manila and there was great speculation about the cause, not restricted to red tide—which after all could not account for deaths on the eastern side of the bay. Fortunately, authorities soon learned that mussel vendors on the western side, once their product was banned from sale there, were trucking the shellfish across to the eastern, Manila, side and selling them alongside the safe eastern mussels. Road blocks were put up to stop the movement of mussels around the bay and soon put an end to illnesses on the Manila side.

Pyrodinium red tides were becoming a serious public health problem in a widening area of Southeast Asia. While there were no more reports from Papua New Guinea, red tides had become almost an annual event on the Borneo coast and they were increasing in area and frequency in the Philippines. Indonesia first reported *Pyrodinium* red tides in 1994, but in some areas locals had known about it for many years as “poisonous waters.”

Further northerly movement to Taiwan and then the Chinese mainland or Japan seemed unlikely in view of the colder waters there. But a westerly spread from Borneo to the Malay Peninsula and hence into Thailand’s gulf and along its western shores toward Burma or eastward around Cambodia and Vietnam was a distinct possibility. Indeed, since this account was drafted, *Pyrodinium* cysts were found in northern Vietnam.

Child’s play

There was no shortage of sponsors for a conference in 1989 in Bandar Seri Begawan organized by the Brunei government—and in which I played a large part as participant, co-organizer, co-editor of the proceedings, and publisher—on the Biology, Epidemiology and Management of *Pyrodinium* Red Tides. Support and researchers came from many parts of the world, including Australia, Brunei, Canada, Guatemala, Indonesia, Japan, Malaysia, Papua New Guinea, Philippines, Singapore, Thailand, and the United States as well as from international organizations. It was intellectually exciting to rub shoulders with many of the "big" names, experts whose papers I had devoured in my tiny laboratory in Port Moresby years before. Even nicer was realizing that my shoulders were being rubbed by them! However, that conference was my swansong on the subject; I had nothing more to offer and was becoming irretrievably immersed in developing-country fisheries problems.

For this meeting, I has assembled enough evidence to show that everything had started with one child—El Niño, a Spanish term meaning 'the child,' in this case, more particularly the Christ child. It was the term used by South American fishers to describe a warm water current in the sea that occasionally came around Christmas time.

I had long thought about what was so special about one time and place, Port Moresby in 1972, that could cause an unprecedented poisoning outbreak. The accumulated knowledge of more than 45,000 years had no answer to the riddle. It was a question that could not be answered at the time. It is only after such events that we can compare them with the past and look for differences in seasonal patterns.

I could, however, look for unusual happenings elsewhere and standing out like a beacon was the concurrent massive collapse of the anchovy fishery on the other side of the Pacific Ocean. The fishery had built from nothing to more than 10 million tons per year over two decades. It was the largest fishery in the world and being overfished by 1972, but the trigger for its collapse was a strong El Niño. This warm current, when it occurs, displaces the normal upwelling of cool, plankton-rich water that feeds the anchovies. This lowered the fish population and pushed most of the remainder offshore, where they were inaccessible to the fishing boats. Equally interesting, red tides were a regular event there during El Niño seasons.

Japan suffered its worst losses from red tide in 1972, when red tide killed vast numbers of fish in farms in the Seto Inland Sea, worth about US$70 million.

On the Atlantic coast of north America, an unusual, tropical storm in late 1972 resulted in a massive red tide in western New England and a number of nonfatal poisonings from algae, closely related to *Pyrodinium*, that were never before known to bloom there in this manner. Was it coincidence that so similar and unusual an event occurred on opposite sides of the globe in the same year. In the case of New England, poisonous red tides have occurred almost every year since then.

Could El Niño have affected New Guinea so far away? Not much was known about the phenomenon in the early 1970s. But weather, current and temperature patterns over the years were available, and the 1972 event galvanized oceanographers into action. They were soon able to state that the previous El Niño-like event of this magnitude was in 1925, nearly 50 years before.

El Niño is now known to be a major oceanographic event that generally originates on the west coast of South America and results in warmer, windier and drier conditions in the western Pacific, including Papua New Guinea. Its effects on climate and oceanic conditions are sometimes global, affecting even the Weddell seal population in Antarctica.

More evidence accumulated during later El Niños to imply an association with new, poisonous *Pyrodinium* outbreaks. A minor El Niño season occurred in 1976-1977, coinciding with the first Brunei *Pyrodinium* red tides and poisonings.

The next strong El Niño was in 1982-1983. This time oceanographers, climatologists, and biologists were more observant. On my doorstep was the first Philippine *Pyrodinium* red tide, echoing the Papua New Guinea situation.

The worldwide reach of El Niño was becoming more and more apparent the more scientists looked. The 1982-1983 event caused storm surges along the southern California coast resulting in $300 million worth of damage, with 10,000 people having to be evacuated. A pod of bottlenose dolphins migrated north along the west coast to a point near Santa Barbara, extending their known range; the dolphins have remained there ever since. Long standing kelp beds in the area were wiped out and did not begin to recover until 20 years later. Californian sea lions and Risso's dolphin populations mysteriously declined. In Peru, more than three quarters of all sea birds were killed, mainly because their food fish moved out of their range.

More than 11,000 kilometers away in Australia, total damage from drought and storms from the 1982-1983 El Niño was estimated at three billion dollars. The international magazine Time ran a cover picture of a large Australian dam, completely dry in 1983 for the first time on record. Much of the near-surface corals in the Great Barrier Reef were killed or damaged, an occurrence that was repeated across coral reefs in both the eastern and western Pacific.

The 1982-1983 El Niño surpassed the 1972 event to become the worst one of the century. The US National Aeronautics and Space Administration (NASA) estimated the worldwide cost of the damage it caused at over $8 billion.

The next major El Niño in 1986-1987, was comparatively minor in global impact. It did, however, coincide with a second major *Pyrodinium* outbreak in the Philippines. Red tides became an annual event in the country after 1987, but probably the worst outbreak was in 1992, during another minor El Niño period. By 2005, *Pyrodinium* red tides had occurred in 27 separate parts of the Philippines, causing 123 known deaths in a total of more than 2,000 reported poisonings. Closure of shellfish harvesting grounds has become an annual routine in many areas in the Philippines, courtesy of the now regular *Pyrodinium* blooms there.

In one of its “home” grounds, on the Pacific coast of Central America where it had long been recorded as nonpoisonous, *Pyrodinium* suddenly formed a deadly red tide during the major 1986-1987 El Niño. On the Pacific coast of Guatemala, 187 people were hospitalized and 26 died. It bloomed again two years later in Central America, causing further poisonings and death. At the same time, a major red tide in Florida drifted northward into North Carolina waters for the first time and persisted there.

During the 1993-1994 minor El Niño period, more than 180 shellfish poisonings were reported from New Zealand and Indonesia reported poisonous *Pyrodinium* red tides for the first time. In the Indonesian case as in northern (but not southern) Papua New Guinea, residents in other parts of the country had known about it for many years.

An El Niño in 1997-1998 later became the strongest on record. *Pyrodinium* by this time had filled most of its possible niches, but a series of massive red tides moved southwest from China through Hong Kong, causing big red tides of different poisonous algae along the way. In Hong Kong, a red tide killed more than $30 million worth of caged fish. In west Sumatra, Indonesia, there were extensive coral deaths and a massive red tide extended several hundred kilometers along the island chain. More generally, this El Niño caused droughts on both sides of the Pacific, another bad fisheries season in Peru, and extreme rainfall and landslides in southern California. Even the Panama Canal was affected: shipping was restricted due to below-average rainfall.

It was fortunate that *Pyrodinium* began to wreak havoc when it did, when El Niños were still uncommon. They have been increasing in frequency to the extent that only one or two years separate them, implying that there would already be a 50% chance of a new red tide occurring during an El Niño, even were there no association.

What precisely triggered each outbreak? The general recipe in text books is calm and sunny weather. Neither was necessary with *Pyrodinium*. They were definitely associated with the rainy season.

Nutrients in run-off from land were one possibility; nutrients from adjacent mangrove areas stirred by the offshore winds another.

One other possibility has nagged me all these years. One graph in my *Pyrodinium* "magnum opus" showed how red tides in Port Moresby Harbour gradually declined over a full month toward the end of the rainy season as atmospheric pressure fell, until right at its nadir, they disappeared. Atmospheric pressure rose steeply in the following days as the offshore wind returned with a vengeance and I was treated to the strongest red tide I had ever witnessed in the harbour—even though it was a very cloudy day.

Only when I was preparing these notes did I realize that atmospheric pressure is the other half of major El Niño events. Pressure drops over the southeastern Pacific, whereas in the western Pacific, including Papua New Guinea, atmospheric pressure rises. The situation reverses after the El Niño. It is called the Southern Oscillation (SO); El Niño (EN) events are more strictly termed ENSO events.

Was I seeing in my observations in the harbour the pattern of an unfolding ENSO in miniature, condensed in time and space? It remains an intriguing possibility that something as simple as air pressure could be the final trigger—all the other explanatory factors like sunshine, calm weather, upwelling, nutrients in run-off, and combinations of them have never quite filled in the whole jigsaw puzzle.

At least we can say with some certainty that something about major El Niño conditions is responsible for new and poisonous *Pyrodinium* outbreaks where they have been apparently been absent or not poisonous before. The organism itself in all cases would have been present for many years in sediments as an accumulation of cysts, which, as I mentioned earlier, form when conditions are no longer favourable for red tides.

But there were still more questions to be answered. A key one was why *Pyrodinium* red tides became poisonous in El Niño years and, it seems, remained poisonous, while in previous years they were either absent or not poisonous.

World's most wanted

Pyrodinium has become an emerging public enemy on both sides of the Pacific. On the Pacific coast of Central and North America where the first outbreak was in 1987, *Pyrodinium* has not only caused poisonous red tides but has also made pufferfish flesh poisonous—presumably the result of the fish eating accumulations of cysts or cells in a decaying bloom—with a poison called saxitoxin puffer fish poison to distinguish it from tetrodotoxin, the other killer poison in pufferfish.

By the end of its first 30 years of becoming poisonous, *Pyrodinium* had risen to become the world's "most wanted" human poisoning agent in shellfish, accounting for more than 40% of all reported PSP cases in seven continents. Should I feel proud to have been present at its "birth" in 1972, an accidental midwife? It was a privilege to have been the first person to set eyes on a poisonous *Pyrodinium* red tide but little did I suspect it would become a global public health concern.

It wasn't the only dangerous red tide, of course. The red tides that were killing Japanese pearl oysters and fish in farms were of a different kind and worse in their economic effect. They have prompted some interesting ideas on defeating red tides. One is to prevent the red tide cells getting all the nutrients they need by spurring the growth of other, harmless algae like diatoms. It would be a balancing act of the first order: irradiate the sea bed with strong lights hung from a vessel to wake up the resident diatom cysts there at a time when there are a lot of nutrients in the surface waters but before the red tide cells find out about the nutrients! I think that is an idea that could easily backfire!

Another idea is to use viruses, which can reproduce very fast, to exterminate a red tide. There are known algicidal viruses that could be cultured in laboratories and poured onto the red tides. One slight problem is that they might also kill harmless algae in the plankton as well, disrupting the entire food chain and starving shellfish—like pearl oysters!

Harmless was a word that was in the past always applied to *Pyrodinium*. Could it really be the cause of the deaths in Papua New Guinea? Confirming evidence was to come from the US: in 2002, *Pyrodinium* in the Indian River Lagoon of Florida in the Atlantic Ocean began form red tides and produce the same toxin as that found in the Indo-Pacific outbreaks. Prior to that event, *Pyrodinium bahamense* was separated into two types, or subspecies, partly on the grounds of toxicity; the Florida type was in the non-toxic group. By becoming poisonous there, *Pyrodinium* created yet another mystery to confuse the scientific and medical world.

Two exciting research findings this century have confirmed my ideas, my theories, about the origin of *Pyrodinium* in the South Pacific and Southeast Asia. One is the discovery of where the poisons reside inside *Pyrodinium* itself and the other gives good evidence that it is indeed a newcomer to the region.

In the late 1970s, a few scientific articles had begun to record the presence of bacteria in dinoflagellates and speculated about their function, particularly as the source of toxins; I read these avidly and felt that the bacteria had a role in poisoning by being expelled or "exposed" when *Pyrodinium* shed its armour, which, I concluded after my experiments on this matter, was when *Pyrodinium* became poisonous. That would mean the poison was associated with the bacteria not the algae themselves.

In 2006, a group of Philippine scientists led by Patricia and Rhodora Azanza published a report in the prestigious journal Microbial Ecology showing that *Pyrodinium* was host to quite a variety of bacteria within its cell, living in symbiosis—meaning a relationship in which both partners gain an advantage, what we call nowadays a win-win situation. Nearly all the major bacteria types they found proved to contain the paralytic shellfish poison! How amazing that tiny *Pyrodinium* lives with so many kinds of even tinier partners; and their numbers, sharing its suit of armour, must be prodigious.

I was reminded of the old saw: “Big fleas have smaller fleas upon their back to bite them; and those fleas have lesser fleas and so on ad infinitum” in an 18th century poem by Jonathan Swift. It also begs the question: are the poisons from the bacteria themselves or from symbiotic viruses within them—just as there are algicidal viruses—and what do the viruses harbour? Those are questions for future generations of dinoflagellate detectives.

Another carillon started pealing when I read about these bacteria. In a more macroscopic world, anemones, corals and giant clams have in their tissues symbiotic algae called zooxanthellae. Corals, when stressed, in their case usually by excessively warm water, expel their zooxanthellae and become bleached, that is they turn white because it is the zooxanthellae that give them their colour (the beautiful “lips” of giant clams too); if the corals survive they grow new colonies of the algae. And guess what? Zooxanthellae are naked dinoflagellates (have no suit of armour) related to that toxic Florida red tide! The system of shedding symbionts for one reason or another is thus not a new concept, but there the similarity ends, or does it?

I was convinced that *Pyrodinium* shed its armour and then became poisonous. It was probably shedding some or all of its symbiotic bacteria in the process. These bacteria and their poisons, toxic metabolites, would be easily taken up by bivalve shellfish like oysters and pearl oysters—bivalves can filter a prodigious amount of seawater, some 10 to 20 or more litres per hour, from which they filter out their food and absorb, for instance, bacteria or the toxins released by bacteria. And my experiments implied that if these toxic chemicals—most such organisms produce more than one—are concentrated enough in the surrounding seawater, they would also deter small or larval fish and other tiny potential predators from approaching the naked red tide cells.

I have never seen the question posed as to *why*—as opposed to how—red tides are poisonous, either making shellfish poisonous to eat or killing fish in the surrounding water. Asking it now, I believe the answer is: *Pyrodinium* uses its bacterial chemical weapons as a defence mechanism to protect the naked cells. In the case of armoured dinoflagellates, this is when they have shed their shells and explains why they are not always poisonous; and why naked poisonous dinoflagellates, like that in Florida, always produce poisons.

The second piece of research was the discovery of "old" *Pyrodinium* cysts. My Suez Canal theory would mean that cysts of *Pyrodinium* in Southeast Asia and the Pacific should date from post-1869. The oldest cysts in sediments in Manila Bay have been found to date back (so far) only to the 1920s. But in two areas in Indonesia, they were found to be considerably older. The researchers concluded that the cysts first appeared in about 1850 and were "continuously observed" in sediments from around 1870. They used ash from the 1883 eruption of Krakatoa as a reference point.

I found this wonderful confirmation of my theory that they were aliens imported from the Persian Gulf area, and, although it opened only in 1869, most likely via the Suez Canal. After all, it would be difficult to be completely accurate about ash sediment dates in shallow bays affected by a massive eruption that annihilated half of Krakatoa Island and sent tsunamis and shock waves around the world.

Also, Indonesia is chronically wracked by massive eruptions. Mount Tambora, in Indonesia's Lesser Sunda Islands, erupted in 1815, the largest volcanic eruption in recorded history. It changed the weather worldwide due to the clouding effect of the huge amounts of ash spewed into the atmosphere; the next year,1816, was called the year without a summer because across the northern hemisphere, crops and livestock were decimated; it caused the worst famine of the 19th century. Nearby on Java, there was a large eruption of Semeru volcano in 1860; Makian volcano, on Makian Island west of Sulawesi, erupted violently the next year. There must have been a lot of ash around. In fact, Indonesia has more historically active volcanoes (76!) than anywhere else, and the most number of damaging eruptions in terms of fatalities and damage to land.

And, if not as aliens, where could *Pyrodinium* cysts, absent in earlier sediments and which do not float, have possibly come from?

And after all the experimentation, guesses, and surveys by me and successors, it all seems to boil down to a microscopic single-cell marine plant, an alga, that has been carried as cysts by us humans to new environments through no fault of its own, and sometimes prospered so well that it overwhelmed all the other plankton when conditions favoured it, then formed cysts again to hibernate when conditions turned unfavourable. Could *Pyrodinium* cells speak, they would probably apologise for the release of poisons in their new backyard—blame the unruly bacteria, not us, they would say.

Oysters, Red Tide, and Climate Change

The deaths of those three children near Port Moresby in 1972 were momentous for two reasons: they put to an end an element of wisdom that had until then kept people safe and was handed down through countless generations, and they signalled the beginning of the new climatic era—marked by increasing major El Niños—the beginning of noticeable global warming. Air temperatures across the world have actually been increasing slightly since the 1850s when the industrial revolution began to gather speed under steam power. But the warming accelerated from the mid-1960s as western economies boomed, setting the stage, you could say, for the event of 1972.

There is no doubt that temperatures around the world are rising, whether or not due to the increase in amounts of gases pumped out by industry and transport, and to an extent also from agriculture. These gases, mainly carbon dioxide, nitrogen oxides, and methane are known to cause a greenhouse effect in our atmosphere—heat, too much of it, is trapped in the atmosphere instead of being released out of it. The resulting damage is benignly called climate change, an idea that would have been laughed at in 1972. But the 1972 major El Niño was, as we have seen, followed by others with increasing frequency. They have become one of the most fearsome features of climate change.

Rising temperatures also mean more severe storms: in the Pacific, a cyclone swept across Niue in 1990 destroying nearly all its infrastructure and agriculture. It turned the country from a food exporter into one dependent on imports for the next two years; another cyclone in 2004 was almost as bad. The Cook Islands with its bourgeoning pearl culture industry had five cyclones in one month in 2005; and three of them were about as powerful as cyclones get! In the last century the Cook Islands experienced such powerful storms on average only once in 20 years.

This can only mean a beak and uncertain future for black pearl farming, which is currently increasing around the Pacific islands. Black pearl farms are now economically important in Fiji and the Marshall Islands as well as in Tahiti and the Cook Islands. The pearl farms in the Cook Islands, Fiji, and Tahiti have all suffered considerable damage from cyclones in recent years.

Seawater temperature will also increase, by 1 to 3 degrees centigrade by 2100 on the Great Barrier Reef, for example. Since temperature controls the reproductive cycles of many marine organisms, we can expect dramatic effects on them; for instance, pearl oysters may spawn at a certain time and water temperature to take advantage of the prevailing current direction to disperse their young. Warmer water could induce them to spawn too soon and send their young into a different current ending up in an inhospitable habitat.

Water expands as it warms and sea level could rise by up to 30 centimeters by the end of the century from just one degree rise in temperature. Even greater danger lies in the melting of the polar ice caps, something that is also accelerating at breath-taking pace in recent years, with consequent concern that sea level will rise much higher. Already some low-lying Pacific atolls are being inundated and their inhabitants relocated to higher islands, the first being the Carteret Islanders of Papua New Guinea. Low-lying countries like Kiribati, the Maldives and Tuvalu have begun negotiating mass migration of their populations to other countries. Pearl farms could lose their land bases in low-lying areas.

The climatic consequences of global climate change in the Pacific are alone cause for concern about the safety of oyster and pearl oyster farms. But a far greater longer-term problem has now been recognized. The main gas causing global warming of the atmosphere is carbon dioxide and as it increases in the air, it also increases in the oceans. The oceans normally absorb about a third of all the carbon dioxide produced in the air.

The root of the problem is that when carbon dioxide dissolves in seawater it forms a weak (carbonic) acid. As that acid gains strength, it lessens the amount of calcium carbonate available in the sea for animals to use. Calcium carbonate is the chemical that makes up the shells of shellfish, like pearl and edible oysters, and clams; the corals need it to make their skeleton; so do fish—it's all calcium carbonate. You can see how vitally important to marine life that carbonate is! The ocean has already been slowly becoming more acidic since the industrialization process began to spread around the world; now, acidification is speeding up.

Even if those weakened pearl oysters can still be farmed into the distant future, their ability to make pearls might be weakened too; pearls are made of the same material as the shells—the quality of the nacre could decline or it might take much longer to grow pearls. Coupled with the prospect of worsening cyclone damage to pearl farms in the future, the industry may well close down worldwide.

Generations in the distant future will wonder where those massive pearls with their white, golden or black luster could have come from. Black pearls will revert to legend and myth. However, production of less valuable freshwater pearls will probably continue, a sad reminder of a rich past.

The predicted temperature rise in the ocean may be small but that slight (average) warming might be enough to expand the areas where red tides are currently a concern, or bring some of those dormant cysts back to life from the seabed. Many poisonous algae have these cysts.

Pyrodinium is harmless to shellfish, including pearl oysters, but it is not the only tropical red tide. Since the world-changing El Niño of 1972, fish and shellfish killers have arisen as well, including in the Persian Gulf, where a fish killing red tide occurred for the first time in 1999. The Gulf of Mexico is now regularly treated to similar red tides. Over the past decade or so, outbreaks of new fish-killing red tide organisms have been reported virtually every year, such as in Chile, Gulf of California, Hong Kong, and Indonesia.

"Whatever the mechanisms," the Woods Hole Oceanographic Institute, a leader in harmful aquatic bloom (red tide) research, states, "coastal regions throughout the world are now subject to an unprecedented variety and frequency of HAB [harmful aquatic bloom] events."

Australians love their oysters but warming seas could change that overnight. Imagine a poisonous *Pyrodinium* red tide passing along the bays where they are grown. With global warming and given the former presence of *Pyrodinium* in the home of the famous Sydney rock oyster, the future may well hold this threat. Precautionary measures would probably mean taking oysters off the menu in their peak season.

The future looks brighter for red tides, which will no doubt appreciate the warmer conditions, the higher rainfall that will bring more nutrients in runoff from land, stronger storms to whip the nutrients up from sediments on the seabed, and El Niño conditions with their trigger of increasing atmospheric pressure and its effects on winds.

Of course, when shellfish are finally unable to grow any more, we won't have any problems from shellfish poisoning either!

It is all so unfair on the Pacific islands and their populations. They produce negligible amounts of greenhouse gases. Who could have foreseen these terrible consequences of human industry in the "innocent" 1970s, when everything seemed to be static? Scientific and technical problems in, for example, oyster and pearl culture, once solved would be solved forever. Now, the bleak prospect is that it was all in vain. The very seas are changing, making marine life—not just oysters, but many other marine animals—more and more vulnerable to extinction.

Scientists have been predicting that simply by overfishing the oceans, as practically every nation now does, we will have to eat smaller and smaller kinds of seafood in the future as we eat our way down the food chain from carnivorous tuna and swordfish, now under threat, to plankton-eating fish like herrings and anchovies, and then to jellyfish.

While the idea was treated with derision as recently as the end of the twentieth century, it is a process that was already well under way; jellyfish are beginning to be a regular seafood item in some countries. Climate change is speeding up the demise of some marine life; our growing appetite for seafood combined with our growing population could well wipe out much of the remainder.

When the jellyfish have all gone, we will be left with only plankton soup to eat. But ironically, much of that plankton could be—red tide.