PEOPLE AND NATURE
Ecological Issues

THE OCEANS

David Tranter[1]

(Final Draft)

(a) Ocean Dynamics

Accustomed as we are to life on land, we tend to forget that it is the ocean, not the land, which occupies the greater part of the earth's surface - the restless, mobile ocean - and the land is in its way! Exposed by day to the full force of the sun, the surface of the sea absorbs enough energy to set the winds in motion and the ocean follows suit. Cool air is drawn from high latitudes to low to form the trade winds and as the seasons change they follow the sun across the equator. Combining with the eastward spin of the earth, the trades drive equatorial currents westward toward continental shores where poleward western boundary currents such as the Gulf Stream and East Australian Current are formed. Hugging the continental shelf, these currents distribute warmth to higher latitudes and spawn large warm and cold-core eddies which chase their tails for months at speeds of several knots until they are swallowed up by the surrounding sea. Closer to the coast, nearshore currents pick up sand and deposit it on beaches and river mouths to form coastal lagoons, while tidal currents rush through narrow straits drawn by the pull of moon and sun. In ways like these, the global ocean discharges and recharges its batteries, interacting feverishly at times with the atmosphere to form cyclones and tornados that make light work of the feeble handiworks of man.

As cold eras alternated with warm during the ice ages, ocean and atmosphere reversed their respective roles as source and sink for carbon dioxide in response to such factors as: the advance and retreat of snow and ice across land and sea; the pace of deep-sea circulation; and the higher solubility of carbon dioxide in cold seawater. During glacial periods carbon dioxide flows from land and atmosphere into the freezing ocean where it is now more soluble. As sea-ice forms it extrudes brine, leaving matrices within the ice that are colonised by siliceous algae and bacteria. In summer, when the sea-ice melts, sticky algal aggregates released into the water column sink quickly to the bottom, the habitat of a rich, recently-discovered sea-floor fauna. Salt-enriched by the formation of (low-salinity) sea-ice, cold, saline waters at the sea-ice edge become so dense and heavy that they sink like a gigantic waterfall in slow motion carrying their load of dissolved carbon dioxide into the ocean deeps and across the ocean floor, ventilating the abyss. This "suction pump" draws carbon dioxide into the ocean through the air-sea interface, depleting the level in the global greenhouse and reinforcing the pace of ice-age advance. Conversely, during inter-glacial periods, the deep-sea circulation weakens and, as carbon dioxide becomes less soluble in the warming ocean, it flows back into the atmosphere through the sea-air interface reinforcing the pace of global warming.

Yet it is this same violent ocean that, over the ages, has combined with the atmosphere, the "placenta of the earth", to keep global temperatures at levels fit for life, providing animals with oxygen to breathe, water to drink and a great deal of their food. Hidden beneath the surface of the sea are food chains based on microscopic algae with glassy, cellulose and calcareous shells, which draw nutrients and carbon dioxide from the surrounding water and energy from the sun to synthesize organic matter. So many

[1] David Tranter OAM, graduate in marine science from the University of Queensland (B.Sc., M.Sc., D.Sc.), is a retired CSIRO research scientist. His first appointment was to Thursday Island where he worked with Aboriginal hard-hat divers on the biology of pearl oysters. For the next 30 years he studied the ecology of marine plankton, taking a leading role in the international co-ordination of- oceanographic and antarctic research. A UNESCO appointment to India for two years taught him that most people prefer a rich life to a life of riches. He is a foundation supporter of the ACF, the NPA (of which he was once NSW Secretary) and other environmental organizations. An honorary life member of Robertson Environment Protection Society and Flower Export Council of Australia, David grows wildflowers on a mountain slope overlooking the Illawarra coast and open ocean.

calcareous shells have been produced since life began that a great deal of the ocean floor is now covered in calcareous ooze. The destiny of this calcareous material is to be buried in the bowels of the earth and there transformed by heat and pressure into calcareous rock, or carbon dioxide which is eventually released into the atmosphere by volcanos. Thus begins the first phase of a long-term global thermostat cycle based on calcium carbonate.

Just as the bloodstream of mammals maintains their bodies at an even temperature, aerates their tissues and transmits information back and forth by way of hormones, so the ocean functions as an external milieu for its plant and animal inhabitants. Its pH and inorganic constituents are so much like blood that it was once thought the two were closely linked. As land plants rely on winds to disseminate their seed, so marine animals shed their eggs and larvae into the sea to be carried away by the currents to distant places.

It is the fate of all open ocean animals and plants when they die to sink towards the bottom where their remains are decomposed. Consequently, bottom water is the main nutrient source for ocean productivity. However the same sunlight that phytoplankton in the upper layer requires to synthesize organic matter also has the effect of stratifying the water column. Consequently, the intervening thermocline inhibits nutrient influx from below, isolating sunlit algae from their nutrients; and because they are nutrient-impoverished their carbon dioxide uptake is limited. As a consequence, the most fertile areas of the ocean are where the thermocline is shallow, where deep waters upwell, or on the continental shelf. In high latitudes, the thermocline breaks down in winter, initiating a spring bloom which sustains the food chain for the greater part of the year.

Feeding on phytoplankton is a wide diversity of small, planktonic grazers whose common characteristic is their ability to filter particulate food; and so the story goes, from one link in the food chain to the next, each grazer and each predator somewhat larger than the one it has consumed until the ultimate morsel is large enough to attract the leviathans of the sea. Those shellfish, crustaceans, molluscs, fish and whales that we harvest for food are the end-product of this cycle of organic production.

While all this eat-and-be-eaten activity takes place in sunlit surface waters, the main site of primary production, deeper-living animals feed on detrital sediment or migrate upward once a day to forage. Meanwhile, down in the abyss, other animals aggregate near the sea floor in places where hydrogen sulphide emanating from the bowels of the earth provides an alternative energy source to sustain organic production.

People are drawn to the edges of the sea to search for food, ancient adventurers crossing the Mediterranean in rowing boats to find new lands to conquer. With the dawning of the Renaissance, a little bit of Western Europe jutting out into the Atlantic sent men out in sailing ships to find new lands, their successors colonising the New World with the help of “guns, germs and steel”.

In the course of time, ports developed along the coast where trading ships could safely anchor. Today the greater part of the world’s population is concentrated there, both for trade and amenity, burning fossil fuels at an escalating rate, oblivious to the danger of rising sea level. Australia, the island continent, lies well away from the main shipping lanes and one can work at sea for months and never see another ship; by contrast, the Straits of Malacca, the North Sea and the Gulf of Maine are alive with ships; there are frequent traffic jams and their lights at night look like a city.

(b) Environmental Impact

The Arctic ice-cap is melting much faster than expected. Should this melting extend to Greenland and the Antarctic mainland, the liberated melt-water would raise global sea levels so high that low-lying lands around the world would be inundated. As people are driven from their native lands in search of refuge they tend to leave in small, unseaworthy boats and face a miserable death at sea. To date, the stream of refugees has not been very great, but the flow would surely escalate should the low-lying areas of heavilypopulated nations like Bangladesh be swamped. If the continental ice-cap does retain its integrity, the level of the sea will still rise, due to temperature-induced expansion, but the rise is unlikely to exceed one metre.

We tend to think in a linear kind of way, some more linearly than others. The ocean doesn't work that way; its processes are highly interactive. It is common in the ocean and the atmosphere, its partner, for effects to influence their cause. Such feedbacks come in two different forms: negative (where the effect moderates the cause) and positive (where the effect reinforces the cause). The problem with positive feedback is that it carries a sting in the tail: its destabilizing consequences are sometimes irreversible. The combustion of fossil fuels, for example, is gradually acidifying the sea and dissolving the shells of calcareous organisms, plant and animal alike, compromising the ocean's capacity for long-term regulation of the earth's temperature. Another example is the sea-ice factor: Sea-ice reflects back to space a great deal of the heat it receives from the sun, reinforcing the freezing rate; conversely, when the sea-ice begins to melt, the dark-blue sea that it exposes absorbs the heat of the sun reinforcing the melting rate. A third example is the reinforcing effect of the thermocline on global warming: as the thermocline becomes stronger under the influence of global warming, and its oceanic expanse becomes wider, phytoplankton capacity to take up carbon dioxide decreases and the surface layer of the ocean changes from a carbon dioxide sink to a carbon dioxide source; the consequence is reinforced global warming. It is therefore of some concern that few quantitative data on such feedbacks have been available to the Intergovernmental Panel on Climate Change to include in their models. Their Report (IPCC 2007) is consequently conservative; the real situation could be worse.

From time to time, an oil tanker comes to grief and spills its load into the sea, as in Torres Strait in 1970 when the Oceanic Grandeur skimmed a reef at low tide. The oil that is lost suffocates the fauna on the sea floor and coats seabirds with oil they can't remove. But there are worse pollutants than oil. The seawater that tankers use for ballast contains larvae of exotic species which, when released nearshore in virgin habitats, can proliferate like weeds wiping out valuable local species. Tankers should be required to empty their ballast water out in the open ocean where their unwelcome cargos are less likely to survive.

Not so long ago it was said that we knew more about the far side of the moon than the deep-sea floor. Bottom trawling is much like sending a probe from an orbiting satellite through an opaque atmosphere to sample life on the surface of an unknown planet. For centuries, that has been the way that bottom fish have been caught. Inevitably the trawl takes everything in its path except for animals smaller than the mesh. The catch is then dumped on the deck and sorted into catch and by-catch, the latter unceremoniously returned to the sea with little chance of survival. Bottom trawling scours the sea floor and damages the community of animals from which the catch was taken. It is therefore not surprising that continued bottom trawling has resulted in diminished catches. The first attempt to assess the extent of this damage was by CSIRO ecologist Keith Sainsbury, who persuaded the Australian Government to set aside a virgin area of the Northwest Shelf as a control by which to judge the effect of trawling on an adjacent fishing area. Underwater photography of both test and control demonstrated the impact of trawling for the first time, for which research he was awarded the Japan Prize, the most distinguished international award in ecology.

The long-lining technique for catching fish such as tuna, which forage in the water column rather than on the sea floor, was pioneered by the Japanese. More than 500 longline boats from more than 30 nations are at sea each year, chiefly in Alaskan waters and the Southern Ocean. Fifty miles or more of line with several thousand baited hooks are fed out by each ship across the surface of the sea and hauled in again a few hours later. Some 5 million hooks are set each year. Hungry sea birds like albatross, whose habit is to target any fish they see, cannot discriminate between live squid and squid on baited hooks, so they get impaled. Secured by their beak or throat they are unable to escape and are drowned. Thousands die in this way each year, including the large Wandering Albatross, which has a wing span of up to eleven feet. The consequent mortality is greater than most conservation-minded countries are prepared to accept, particularly since it can be avoided by weighting the longline so the baited hooks sink more rapidly out of reach of foraging sea birds.

Those without the wherewithal to fish at sea, particularly in Southeast Asia, frequently use dynamite to take fish from coral reefs, where the pickings are more accessible. As with bottom trawling, the impact does not discriminate between target fish and bycatch, destroying both the inhabitants of the reef and the reef itself.

© Overfishing

It is not without reason that each generation of fisher folk believe fishing to be not as good as it once was. In the early part of the 20th century, the nations of Western Europe set up the International Council for the Exploration of the Sea (ICES) to monitor the catches and control the yield, treating each target fish in turn as an isolated entity and studying its population dynamics to identify a maximum sustainable yield. The most vulnerable fish of all are those that forage on the sea floor such as Atlantic Cod. Canadian stocks of cod collapsed after 20 years and, of the North Sea stocks estimated at about 50,000 tonnes, less than one third of the sustainable minimum still remains.

As more and more boats were built and their technology improved, each target fishery declined until it became more economic to abandon the overfished in favour of a virgin population. Right now, about one-third of the world's commercial stocks have collapsed and the decline is accelerating. The practice of sampling the catch to study a target population is flawed at the outset, externalizing as it does the community from which the target catch is taken - a practice not unknown in economics.

The Southern Bluefin Tuna is an Australian icon. A magnificent fish, it roams the Southern Ocean feeding on small fish and squid, migrating north to breed in an area south of Java where periodic upwellings generate food of smaller size to sustain their offspring. Drifting south with the El Nino-driven Leeuwin Current, the young are carried around Cape Leeuwin, getting bigger as they go, across the Great Australian Bight, up the southeast Australian coast a way, then out into the Tasman Sea, providing pole-fishing opportunities for coastal tuna boats operating out of such ports as Port Lincoln and Eden. While Australia harvests the juveniles, Japanese and Taiwanese long-liners patrol the Southern Ocean taking the adults. Despite continuous monitoring of fishing pressure, the population has declined from about 75,000 tonnes to about 15,000 tonnes over the past 45 years and there are real concerns that the fishery is endangered.

By the time Australia was colonized, American whalers and sealers were already wandering the oceans of the world searching for animal oil. Early explorers across the Nullarbor were astounded to find large whaling fleets at anchor in what is now Albany. Before long, enterprising Australians were harvesting whales from long-boats in the Eden area. Immediately after World War I, open-ocean whaling got into top gear in the Antarctic, taking one whale species after another, starting with the Blue Whale, the largest animal that the world has ever seen. As stocks declined, whalers moved to smaller species, taking each species to its economic limits, then moving on to even smaller species. Now their target is the Minke Whale, the smallest whale of all.

Ongoing British studies at the main Antarctic whaling base in South Georgia have revealed a surprising phenomenon: As whale stocks declined to the brink of extinction, those seals that feed on the same food source (Antarctic krill) began to multiply, demonstrating how closely the components of Antarctic ecosystems are interlinked. As a result, the International Commission that was set up in Tasmania to manage Antarctic stocks began to consider the Antarctic ecosystem as a whole rather than by species. The limitations of population dynamics in fisheries management led ultimately to the alternative strategy of "adaptive ecosystem management" in which Australian scientists led by CSIRO played a major role.

Immediately after World War II, whaling bases were established at Northwest Cape and Tangalooma (South Queensland), to take humpback whales on their annual northward migration from the Antarctic; by then their populations were already in decline. Before long, countries like Australia began to ban further whaling. Soon there were signs of recovery, starting with the smaller, faster growing species. But some nations such as Japan and Norway have ignored the ban, continuing to take Minke Whales for scientific purposes. Meanwhile, whale-watching has begun to flourish throughout the world, boosting the tourist industry.

(d) Ocean Potential

Nowhere else are interactivity and feedback as keenly appreciated as in oceanography, meteorology and ecology. The term *ecology* was coined by the German planktologist Ernst Haeckel to describe studies of *the household of nature*. It took a meteorologist (Albert Wegener) to challenge the fundamental geological wisdom of the day that continents are fixed in position on the face of the earth; and it took oceanographers to explain the dynamics of inter-annual (El Nino) drought. As the world's resources, such as land, water, food and fossil fuel are stretched to their limits, a phase change is required in our understanding of Nature if we are to survive and prosper. The ocean is a storehouse of such information and a source of new opportunities.

It is the ocean, rather than atmosphere, that is the better predictor of long-term weather. Nowhere is this better illustrated than with the El Nino Southern Oscillation (ENSO) which drives the pan-Pacific drought cycle. When the equatorial thermocline in the Eastern Pacific is too deep for diving birds to reach their prey, they starve in their millions, at which time Australasia is in drought; conversely, when the prevailing trades pile warm equatorial waters up against Australia and the East Indies, the resultant heat engine lifts humid air on high and the rains returns to our part of the world. This (ENSO) cycle lasts from 3-7 years, its passage evident month by month across the equatorial Pacific in sea surface temperature and thermocline depth, early warning signals of the climate just ahead. The sciences of oceanography and meteorology are inter-twined, their weather satellites monitoring the sea surface, their anchored buoys monitoring the water column. Should the Arctic ice cap melt much more, the freshwater that would be released would dilute the sea so much that it would slow down the density-driven circulation that drives the Gulf Stream, the system that keeps the greater part of Western Europe much warmer than like latitudes elsewhere.

There are opportunities for reclaiming sustainable energy from the ocean which would otherwise dissipate in turbulence. The ocean is a gigantic powerhouse, converting heat from the sun into a variety of fluid motions which could readily be harnessed, particularly in Australia where the population is concentrated near the coast. Immediately offshore from Sydney, where there is plenty of open space, batteries of interlinked wind and current farms could be built across the continental shelf to harvest energy from land-sea breezes and longshore currents, feeding power by high-voltage DC cable on the sea floor to the main state power grids. Similar opportunities exist in remote places such as Torres Strait and the Northwest Shelf where tidal currents race back and forth by night and day at speeds of up to seven knots. In places like Christmas Island and Kiribati, where there are deep, cold waters close to shore, there is scope for ocean thermal energy conversion (OTEC). There is also energy in the waves that break incessantly upon exposed coastlines and energy in the winds which could be used to fill the computerised, rotatable sails of the next generation of ocean liners and tankers. Large maritime cities like New York, Rio, Tokyo and Sydney could recirculate nearby seawater to reduce their air-conditioning costs.

Nowadays, just as agriculture has replaced hunting and gathering, mariculture is overtaking wild fishing in importance. Here in Australia, the culture of pearls and prawns in warm waters currently leads the field followed, in cooler waters, by abalone, salmon, bluefin tuna and oysters. Perhaps the time has come for calcareous ocean phytoplankton (coccolithophores) to be cultivated en masse at coal-fired power stations to fix their carbon dioxide emissions in a particulate form for disposal in the open ocean where it would sediment out on the deep-sea floor as in nature. Many attempts have been made to extract pharmaceuticals from marine plants and animals, particularly on the Great Barrier Reef (Roche), but so far without a great deal of success.

Some scientists believe that the greater productivity of continental shelves is related to the influx of wind-blown iron from the land, iron being one of the three main prerequisites for primary production. Since large areas of the global ocean are deficient in iron, particularly subtropical areas, the proposal to seed unproductive expanses of the ocean from the air with particulate iron to enhance carbon dioxide uptake may have some merit, particularly if it leads to the production and sedimentation of calcareous organisms.

Nowhere is the diversity of ocean life so well displayed in shallow waters for the world to see as on coral reefs, particularly in Indonesia, the Philippines and Australia. Because of its luxuriance and extent, the Great Barrier Reef is recognized as a World Heritage Area, attracting so many tourists from near and far that it has become a key part of the Queensland economy. Indeed, the east coast of Australia, with its coral reefs, glorious sandy beaches, coastal lagoons and rocky shores is without equal anywhere in the world.

Glossary

Detritus	Dead organic matter such as carcases and faeces
El Nino	An Equatorial Pacific climate phenomenon first noticed in Spanish Peru
ENSO	El Nino-Southern Oscillation; interannual alternation of Pacific Trade Winds and Equatorial Currents which controls the drought cycles in Australasia and Peru
Krill	Shrimp-like grazers about an inch in length; the main food of many kinds of whales, penguins, seals and Antarctic flying birds
Nutrients	Chemicals needed to sustain phytoplankton production
Mariculture	Controlled farming of marine plants and animals
Phytoplankton	Microscopic sized algal plankton
Plankton	Small creatures that drift with the currents
Primary production:	Synthesis of organic matter by phytoplankton
Thermocline	Interface between the warm, nutrient-poor surface layer and the cooler, nutrient-rich layer underneath

Further Reading

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