

phrase, that they "could hardly have failed to notice a change in the style of printing" of the Newsletter. A small offset-printing machine was responsible, and for the next 11 years, countless hours went into producing 2 large Newsletters (subsequently Journals) per year and a number of Bulletins, including a Moss Flora for the Waitakeres by the late John Bartlett, and Jim Beever's very large and very admirable "A Dictionary of Maori Plant Names". This huge spare-time work perhaps could not have been done without help, and I refer of course to Chris Mackinder. The extent of their work is laid out in Chris's "Index to the Newsletters" (to '87), completed by her Index ('88 to '93) in the July '93 Bot. Soc. Journal, that issue also containing Jack's farewell editorial note.

Jack found time to write several articles on Waitakere adventives, and although famous for not botanising elsewhere he also has written on the Botany of St Paul's Anglican Church in Symonds St, and on a large Scenic Reserve in the Hunuas. His own artwork and calligraphy graced our Journal in '89 with two elegiacal sketches from Waikumete Cemetery, in January one of *Watsonia bulbifera*, enhanced with the hand-addition (Chris again) of 2 tones of watercolour; and in July one of *Leucojum aestivum*, this time with 3 colours.

Last year Jack produced a Bulletin of his own on the exotic plants of the Waitakeres. As well as having a cover lithograph and some delightful sketches inside this work also exemplifies his logical approach to minor irritations - I am referring particularly to his note: "Five plants, *Cotula australis*, *Deparia petersenii*, *Diplazium australe*, *Geranium homeanum*, *Geranium solanderi*; "coarse hairs" have been excluded because they are deemed to be native in Vol. 4 of the Flora, although they were also excluded from Gardner's list of the Waitakere Range as non-native." [my italics]

Jack's artistry can also be seen in the beautifully-prepared voucher specimens now in the Auckland Museum Herbarium (AK) - I can say that seeing these for the first time gave me a very beneficial shock, my own specimens of that era tending to be of the "hard pressed" variety. I hope that some of his specimens can be shown at some future plant-groups Bot. Soc. evening, perhaps one especially on collection and preparation methods.

As well as having this busy Bot. Soc. life Jack had moved into teaching computer-programming, readying people for the real world at ATI, and also in readying the real world for people, by using his talents at AK to create a near-foolproof system (the witty AKILLES), which labels and keeps track of plant specimens, a system subsequently taken up by other NZ herbaria.

I think we can be sure that even though he will no longer be serving Bot. Soc. "for the term of his natural life", Jack will continue to give pleasure to us by his elegant and original works, and also by his company, which we hold in the very highest esteem.

**Marine invaders of New Zealand Coasts
Auckland Botanical Society Lucy Cranwell Lecture
6 October 1993, University of Auckland**

Wendy A. Nelson

Lucy Cranwell's contributions to our knowledge of New Zealand marine algae are not as well known as her work on the botany of the Auckland area or her contributions to palynology. She made algal collections particularly through the 1930s, primarily in the Auckland and Northland regions, including collections from the Poor Knights Islands. Good collections are central to systematic studies and Lucy Cranwell's pioneering expeditions and collections constitute a significant legacy for phycologists. Her contribution to phycology has been recognised in the

names of two species of algae endemic to the northern North Island - the green alga *Codium cranwelliae* Setchell and the red alga *Gigartina cranwelliae* Chapman. It gives me great pleasure to add a phycological flavour to the Lucy Cranwell Lecture series.

There is worldwide concern about foreign marine plants and animals appearing on distant shores. Examples of marine aliens that have become troublesome have received considerable attention in the international press as well as in the scientific literature. I am going to examine how foreign marine organisms reach New Zealand shores - and whether or not this is a modern phenomenon. I am then going to present some case studies of particular species and examine what we know about the impact these introduced organisms have had on native species and communities. My examples will be primarily drawn from the algae although I am also using examples from the marine fauna.

We are one of the most remote nations in the world with a generous marine buffer around our land masses. How do foreign marine organisms reach our waters? It is clear that there are natural events which add to our flora and fauna - events which are intermittent and contribute new residents that may become permanent or are just temporary elements of our biota.

Ocean currents are known to transport the young stages of a variety of organisms quite long distances. Studies on recently emergent volcanic islands have shown the timing and sequence of settlement of marine flora and fauna on newly provided surfaces. As well as planktonic organisms - plants and animals that always inhabit the water columns of the open ocean - there are some organisms that have larval or juvenile stages that swim or float at the sea surface for a portion of their lives.

Ocean currents around New Zealand follow a generalised pattern, although the precise position and duration of seasonal flows can vary. To the north of the North Island the East Australian Current flows eastward. A branch of this current - known as the East Auckland Current - flows each summer southward along the east coast of Northland near the edge of the continental shelf. The distance this current extends down the North Island east coast varies from year to year - thus, the influence of its warm water varies.

From the late 1960s and during the 1970s, as SCUBA diving became increasingly popular as a pastime, divers in Northland began to notice the presence of unusual organisms in the waters around the Poor Knights, species more typically found in tropical areas. A number of warm water molluscs were recorded for the first time in northern New Zealand by Powell (1976) who discussed whether their relatively recent arrival into New Zealand waters was accidental, whether they were temporary, intermittent or permanent additions to the fauna.

The behaviour of ocean currents and patterns of weather are closely linked. Relatively recently, the accumulation of climate data and an improved understanding of oceanographic features of the east coast of Northland have helped us understand what is occurring. At the Leigh Marine Laboratory sea surface water temperatures have been recorded for more than 25 years. When the monthly average water temperature is graphed an interesting pattern emerges of warm years followed by cold years. When the Southern Oscillation Index is also plotted, a relationship emerges between climatic patterns across the Pacific Ocean and the temperature of coastal waters. In El Nino years the sea surface temperatures are cool whereas in La Nina years the warmwater currents extend further south and come closer to shore bringing warmwater organisms into the flora and fauna of northeastern New Zealand (Francis & Evans in press).

The warm years - for example, 1970-71 and 1973-75, also 1988-89 - are years in which the water temperature was well above average for many months. In these periods of warmer conditions, the organisms travelling in the water masses settle into rocky habitats. These periods coincide with the sudden reports of interesting tropical and subtropical species appearing at the Poor

Knights as well as sometimes other offshore islands, and occasionally the coastal headlands jutting out from the coast, such as Cape Karikari at Doubtless Bay. The Poor Knights Islands although lying close to the northland mainland coast, only 19 km offshore, are bathed in these currents which do not always penetrate mainland coastal waters. Larvae or juvenile stages travelling in the water masses settle in these warm periods, but either die out when the warm periods end or are not successful at breeding - either because the conditions are not suitable or because the populations are so small and dispersed. There are many records of these waves of recruits - particularly fish and invertebrate species.

The Kermadec Islands also appear to receive waves of recruits from time to time. In the late 1960s and early 1970s the crown of thorns starfish was causing considerable problems in the Great Barrier Reef and other areas of the tropical Pacific. Population explosions of these carnivorous starfish resulted in devastated coral reefs. Crown of thorns starfish were found at the Kermadecs - but these animals appear to be the result of single recruitment episodes. The animals are all of a similar size class apparently having settled as a cohort. They have not been able to reproduce and so subsequently die out.

Human activities add to the foreign arrivals - and this happens in several ways.

1) **Debris rafting** - When large buoyant seaweeds are swept off the rocks and out to sea by natural events such as storm and wave action, complex communities of organisms develop around the shelter and food that these algal surfaces provide. Marine bacteria and other micro-organisms, small crustacea, molluscs, juvenile fish all cluster around and beneath the floating seaweed raft. This is a natural phenomenon.

However I am sure we have all read and seen evidence of the ever increasing amount of human-generated debris floating in the sea - ranging from cut logs, glass floats, fishing gear, plastic bottles and other plastic materials. Much of this rubbish takes a very long time to break down. This debris can support an immense variety of marine life by the mere fact of providing a settlement surface to colonise. Although current dispersed, this debris is human derived and potentially transports species into areas which previously they were unable to reach. Some organisms can remain as floating stages in the plankton for only limited periods. The opportunity to settle and continue the journey in an adult state would extend the ranges of some species very significantly.

2) **Hitching rides** - Another group of organisms travelled to New Zealand, attached to various marine structures or vessels. It is extremely difficult, if not impossible, to plot the precise pathway that an introduction has followed. However, Nancy Adams (1983) noticed in the course of investigating the distributional patterns of New Zealand marine algae that certain species were confined mainly to harbours and sheltered anchorages particularly those frequented by whalers, sealers and traders from the late 18th century and early 19th century. Some of these harbours grew into modern ports, whereas others - such as Port Adventure, Port Pegasus, parts of Fiordland, Akaroa - lapsed into relative isolation.

In the diaries of early seafarers exploring NZ waters - naturalists, explorers, whalers, sealers - there are many comments about the wooden ships having to be careened regularly. This was because the mass of animals and plants hanging beneath the water line significantly impeded the vessels' progress. The flora and fauna attached to these vessels could have come from any number of places visited before the craft reached New Zealand waters. Sailing ships visiting New Zealand waters last century tended to stay in ports for days, even weeks, at a time.

Professor Charles Chilton (1910) published an account "on the dispersal of marine crustacea by means of ships". When the antarctic ship the *Terra Nova* arrived in Lyttelton it was stated in the

newspapers that the sides of her hull were covered with a plentiful growth of seaweed, barnacles and other organisms. Chilton visited the dock and collected some of the scrapings from the vessel - species that included animals not previously recorded in New Zealand although known from other parts of the world. One isopod was present in large numbers and Chilton pointed out as "both male and female specimens were carried together,...the establishment of the species in any favourable locality to which they might be taken would be quite possible".

Modern shipping is not apparently introducing many species through growth on ship's hulls. The combination of anti-fouling paints and short turnaround times in port makes this a much less likely source of adventive species than in earlier times. However, secondary dispersal of exotic species around New Zealand does occur through fishing boats, coastal ships, barges. Pleasure craft travel internationally and around New Zealand waters, they are often moored in particular areas for extended periods, and owners are sometimes less rigorous about anti-fouling treatments than owners of commercial craft.

There are other marine structures which pose a risk - for example, the clip-on side pieces of the Auckland Harbour Bridge towed into New Zealand waters from Asia; the Maui gas platforms towed into New Zealand in 1975 from Osaka, Japan, after a 65 day journey sprouting an extraordinary flora and fauna, some of which was studied and documented (Foster & Willan 1979).

3) Aquaria / aquaculture - Overseas there have been some serious problems resulting from the accidental introduction of non-target species when organisms have been deliberately introduced for aquaria or for aquaculture - for example, disease organisms, parasites, larval stages of non-target species.

In the Mediterranean there have been major problems associated with a green alga *Caulerpa taxifolia* that is alleged to have escaped from the aquarium in Monaco in 1984 and is now a rampant weed on the Riviera, smothering other life. Populations now extend to Genoa in the east and are on the Spanish islands of Majorca and Minorca. In 1992 France launched a \$3 million programme to destroy this seaweed and this year the Spanish are attempting underwater eradication or limitation programmes (Hughes 1992; Luke 1992).

4) Ballast water - An increasingly important source of exotic species and one that is causing concern all over the world is seawater ballast (Jones 1991). Ships started using water as ballast in the late 1870s and early 1880s. It overlapped and then replaced the use of other heavy materials including beach sand and boulders. It is well documented that the use of ballast sand and soils introduced exotic land plants into our flora - for example, a paper in the Transactions of the New Zealand Institute (Kirk 1896) lists 104 species of exotic land plants growing in a ballast heap from the ship Silverstream which had come from Buenos Aires in 1893.

Ballast water is taken on by ships in ports where cargo is unloaded in order to ensure vessel stability in an otherwise empty ship on its voyage to pick up cargo. Ballast water is carried in dedicated ballast tanks and cargo holds which are used as ballast holds. The water is discharged at the port where the loading occurs. Ballast water may contain sediment if taken in shallow water or in water with suspended sediment.

When vessels take aboard seawater they are also taking aboard all the animals and plants growing in that water. In coastal waters this includes not only organisms usually found only in plankton - always floating in the surface waters - but also stages of the plants and animals that may live in other habitats e.g. larvae or eggs of fishes, starfish, crustacea, mollusca, seaweeds as well as resting stages of organisms normally living elsewhere. If the organisms present survive the sea journey and the ballast discharge process they then may form the basis of a

viable population in a new setting. Today very significant quantities of water are carried around the world in vessels.

The role that ballast water and sediment discharge can play in the introduction of marine organisms has been recognised for some time. Examples have been cited in the literature dating back to 1908. However the first sampling of ballast tanks at the end of a voyage prior to discharge was a study carried out in Australia in 1975, which found live invertebrates aboard after a voyage from Japan to Australia.

So, marine plants and animals can reach our waters in a variety of ways. Once introduced to a foreign shoreline, what can happen to an organism? - what characteristics make for 'success' or 'failure' - for benign or rampant weeds? I am going to present some case studies of marine plants and animals that have responded differently to their new habitats. These examples raise various issues about management and / or control of foreign marine organisms.

On the west coast near Wellington, in Porirua Harbour, there is a red subtidal seaweed - *Chondria harveyana*. This species is known only from Tasmania and Porirua Harbour. In the early 19th century at Porirua there was a whaling station that was regularly supplied from Hobart. Presumably this species hitched on ships' hulls and was able to continue growing in this new environment. It has not spread from the harbour - but if one looks at the near-by coastline, this is not particularly surprising. Where is the nearest equivalent harbour habitat? - south along the open coast, into the Cook Strait and then around into the Wellington Harbour, or, up the Taranaki Bight and around to Kawhia. The coastal topography and currents make the spread of this species by natural forces extremely unlikely.

Another example of a foreign seaweed that we have speculated is linked to whaling activities is *Chnoospora minima* (Nelson & Duffy 1991). In 1988/89 divers were surveying subtidal communities in the Marlborough Sounds and Port Underwood as part of a Department of Conservation study. Although 368 dives were made, this brown alga was found at only one site in Port Underwood, where it was locally abundant, growing unattached in about 8 metres of water. This is the only known record of this species in New Zealand although it is widespread in the tropics. How could it have become established in New Zealand waters? Between 1829-38 the Port Underwood area was very busy with southern right whaling activities. The vessels involved travelled backwards and forwards through the tropical Pacific.

Why hasn't this alga spread and why isn't it attached to the substrate? In fact, no fertile plants have been found. In overseas studies, the low temperature limit for reproduction of this species has been found to be 19°C. Port Underwood temperatures are 7-9°C in winter and 18-20°C in summer (mean daily maxima). These temperatures in Port Underwood almost certainly preclude sexual reproduction and spread by spores. This species is flourishing as drift, expanding vegetatively, but if it was in an area of greater current action it would merely be swept away rather than being able to settle. Seaweeds can only really settle onto substrates as spores - reattachment is rarely found. So this species is in no way a threat to native flora and fauna - it does not have the reproductive / physiological capacity to be aggressive in the environment in which it is now found.

Colpomenia durvillaei (previously known as *C. bullosa*) is a brown sac-like seaweed that was first found in 1980 from the Leigh marine reserve (Parsons 1981). I found it in the mid-1980s at Ahuriri, the port area of Napier, and in 1991 at Mahia and north of Gisborne (Nelson & Adams 1991). It has also reached parts of Wellington Harbour, collected from 1988 or so, and now if you go down to the slipway in Evans Bay you can find it seasonally in abundance amongst the other plants. At Mahia and also in the Evans Bay area, this species of *Colpomenia* has the appearance of being a very successful coloniser of space. In the marine environment, settlement space is at a premium. An introduced species that can successfully compete for space is cause

for concern as it may be capable of elbowing out native plants and animals. At present we do not know enough about the ecology of these habitats or the organisms to make any useful generalisations or predictions. *Colpomenia durvillaei* is seasonally important - but how this relates to the seasonal patterns of other organisms is not clear.

In September 1993 this same area of Evans Bay has yielded three new adventive records, all collected unintentionally when I was looking for other plants. One was a species of the red alga *Polysiphonia* not known from New Zealand, a species that is native to North America and has been recorded as adventive in Australia. On this *Polysiphonia* was a tiny epiphyte - another adventive, only known in New Zealand from only one previous collection made in Timaru. I also collected a brown alga *Striaria attentuata* - found snagged on my line when I was out fishing. This species is considered to be adventive to Stewart Island and Otago Harbour and native to Europe. Has it been introduced to Wellington from within New Zealand or is this a secondary introduction from Europe, its original home, or from Australia or South America - two other places where it is now adventive?

Codium fragile subsp. *tomentosoides* is a seaweed that has received a very bad press in other parts of the world. It was first recorded in New Zealand from the Auckland Harbour Container terminal (Dromgoole 1975) and has since spread more widely in the Waitemata and Hauraki Gulf. This species is sometimes known as oyster thief, having done enormous damage to the Chesapeake Bay oyster fishery in the eastern United States. The plants settle as spores onto shells, develop into large buoyant plants, lift the oysters away from the harbour substrate and then they are washed ashore to die. When first recorded from New Zealand, this plant caused considerable concern. This species can colonise floating substrates imperfectly coated with antifouling paint as well as materials with little surface relief. It also possesses a perennial basal holdfast and is physiologically resilient and able to exist in broad and changing temperature and salinity regimes. Twenty years on, this species has not yet become a serious weed problem.

In May last year I was sent a sample of a red seaweed that I had never seen before. What at first glance appeared to be a routine identification problem has turned into a hunt of the identity of this plant. This unknown seaweed was found growing in the Orakei Basin of the Waitemata Harbour. The basin is not tidal but has gateways that allow water exchange. The pond itself is only drained about once a month. A City Parks and Recreation staff member noticed the large amount of seaweed growing in the pond and became concerned at the possibility that the population - which was clearly substantial - might crash, causing unpleasant odours and complaints to the City Council. He was concerned from a water management point of view. Were there sources of nutrients entering the Basin and encouraging the growth of the seaweed? Could the water management or flushing regime for the Basin be altered to discourage the growth of this plant? The plant is not attached to any surface and it has never been found to be fertile. There are about 70 tonnes wet weight of the plant in the Basin. It is not a species from our flora, it has never been found elsewhere in New Zealand, and it is not anywhere else in the Waitemata Harbour. Work on the ecology and distribution of this plant has been carried out by Drs Michelle Stevens and Frank Dromgoole of Auckland University.

This species can not be conclusively identified without the reproductive structures. It isn't spreading outside the area as it can't attach elsewhere and it isn't producing spores. As with the *Chnoospora* example I gave before - in order to be successful macroalgae have to be attached unless they are in an enclosed area or one of very low current activity. The unidentified species is not posing a threat to the wider flora and fauna - although it does show the success possible through simple vegetative growth.

This particular seaweed has a cell wall compound of potential commercial interest. It may not be a nuisance weed but rather have potential to be farmed. We are still pursuing the identity of the plant by comparative studies of its DNA with other likely species, and comparing its

polysaccharides with those of closely related plants (work of Drs Falshaw, Falshaw and Furneaux at Industrial Research Ltd).

Interestingly, amongst the axes of this plant, the most common invertebrate is the introduced Asian mussel *Musculista senhousia* - a shellfish first recognised here about 15 years ago and apparently still spreading. During the past year there has been both television and newspaper coverage about mats of this animal covering areas of the sea floor on the Waitemata, particularly near various north shore beaches.

In the case of oysters, we now rely on an escaped alien for the farmed product. In the early 1970s in the Mahurangi Harbour just north of Auckland, the Japanese oyster (*Crassostrea gigas*) was found in an area where the native oyster (*Saccostrea cucullata*) was being farmed (Dinamani 1971). It is the introduced species which is farmed now, and it is widespread in New Zealand. In the South Island, it was first seen in the Delaware Inlet near Nelson 14-15 years ago and now is well established around Nelson and in Golden Bay. It is not at all clear where the first Japanese oyster in New Zealand originated.

Accidental introductions through aquaculture can become very problematic. When the Japanese oyster was deliberately introduced into the Pacific northeast early this century two species of oyster drill were accidentally introduced and are potential pests of native species. In addition, the brown alga *Sargassum muticum* was introduced accidentally with the oyster spat. In 1972 oysters were introduced from British Columbia to France. In an article in 'Science', a phycologist from British Columbia predicted the establishment of *Sargassum muticum* in the eastern Atlantic (Druehl 1973). This prediction has been realised: this species has clogged coasts and water ways in England, France, Holland, and is now a major pest in the Baltic.

The next examples I am presenting concern introductions via ballast water. *Undaria pinnatifida* is a large brown kelp that was discovered in Wellington Harbour growing on the breakwater off the parking lot of the Freyberg Pool in 1987 by Penny Luckens, a scientist from the NZ Oceanographic Institute (Hay & Luckens 1987). This species is native to Japan and Korea. In 1987 it occupied a limited area around the inner harbour and container wharves - by November 1988 it had extended to the coast off Ngauranga Gorge, past the ferry wharves and beyond Point Jerningham in the east. It has been located subsequently in Timaru, Oamaru, Port Chalmers, Lyttelton and most recently Picton. This seaweed is a highly prized food plant in Asia - known as wakame in Japan - and is grown in very large scale marine farms.

It is necessary to understand some features of the biology of this plant in order to understand how it reached New Zealand, its potential for spreading, and how it may interact with the New Zealand flora. *Undaria* belongs to the brown algal order Laminariales. Members of this order have a life cycle in which the large conspicuous phase (sporophyte) alternates with a microscopic filamentous (gametophyte) phase. Spores produced by the large plants, develop into microscopic filaments which produce eggs and sperm when the environmental conditions (temperature, light) are suitable. After fusion of eggs and sperm, the sporophyte stage grows again. The microscopic phase can last for some time in low light conditions and not become sexually mature - effectively remaining dormant until the correct conditions occur.

It is believed that *Undaria* entered New Zealand waters in salt water ballast. It is highly unlikely that the sporophyte stage, the large plants, could survive on a ship's hull through the voyage from Asia. It is not the physical shearing forces that would be the problem for we know that *Undaria* can survive on ship's hulls in New Zealand waters in extreme weather / sea conditions (Hay 1990). The barrier for the sporophyte would be the temperature change across the tropics. The gametophyte is capable of surviving higher temperatures and would also be more insulated from change in the ballast tanks of vessels. Further, the large plants in both Korea and Japan have a

very high frequency of infection by a small crustacean that eats holes in the blades of the plants. This crustacean only affects the large plants and it has not been recorded in New Zealand.

In Asia *Undaria* is grown in vast marine farms making use of knowledge about the alternation of generations. Cultures of microscopic gametophytes are used to produce new plants for seeding onto ropes. In Japan and Korea the growth of *Undaria* is seasonal - it overwinters as the microscopic phase and then grows as the conspicuous phase from late winter to summer after the changing seasonal environmental conditions stimulate sexual reproduction. One worrying aspect of *Undaria's* growth and biology in Wellington is that it does not have an off-season. In the moderate conditions found here, the sporophytes are fertile virtually year-round and one can find all stages of this plant almost throughout the year.

Undaria pinnatifida has also turned up in Australia, apparently introduced in seawater ballast at the wood-chip port of Triabunna in Tasmania (Schaap 1992). It is proving to be exceedingly aggressive there. The large quantities present in the Tasmanian subtidal are expected to have significant long-term ecological effects. It is predicted to have impacts on commercial fisheries such as those for abalone and sea urchins. Native macroalgae in the Tasmanian system which occupy the same niche are likely to be the most affected. Perennial algae may also be affected by competition for space, and seasonal understorey red alga, the major food for the abalone, are threatened by the shading and loss of habitat. It is not clear yet how much impact this plant is going to have in New Zealand. Most of the habitats it now occupies are disturbed harbour areas, reclamations or wharf pilings. *Undaria* grows very well on hulls, ropes, concrete pilings, walls. What will happen when it encounters large marine farming areas for example in the Marlborough Sounds? - will the mussel lines be over-run? This species is eaten by paua, and there is interest in the possibility of farming it, either as a fodder crop for farmed paua or as a crop in its own right for the food markets of Asia.

The greatest problem that has emerged with marine introductions centres on the planktonic organisms that are carried in saltwater ballast. Within the plankton there is a wide range of plants and animals - many of these are known more correctly as protists. The vast majority of the organisms are benign. Dinoflagellates are protists, found in the plankton, that come in a wide variety of shapes and forms - the majority of which are harmless although some are intensely dangerous, capable of producing extraordinarily toxic compounds.

The life cycle of dinoflagellates involves a cyst or spore form which is found in fine sediment on the seabed and a motile form near the sea surface. The motile or swimming phase forms part of the phytoplankton and may be ingested by filter-feeding molluscs e.g. oysters and mussels. Human poisoning results from eating contaminated shellfish. The shellfish show no ill effects from the dinoflagellates, so human collectors may have no idea of the time bombs that they might be collecting from a naturally contaminated bed if the evidence of the algal bloom has dispersed.

Toxic dinoflagellates have been responsible worldwide for hundreds of human deaths, and the illness of many other people due to eating of contaminated fish and shellfish (including oysters, scallops, mussels). How often food poisoning from eating fish or shellfish is due to toxic dinoflagellates is not known. The forms of human poisoning produced by dinoflagellate toxins vary between species. Marine vertebrates are also affected by toxic dinoflagellates. Mortalities of marine animals are due to physical damage (usually to the gills), oxygen depletion, direct action of toxins and possible indirect effects of the toxins through the food chain.

In addition, in the last few years it has been realised that certain diatoms can produce a toxin (domoic acid) that is capable of killing people when present in sufficient quantities. Diatoms are another group of single-celled plants that live at the sea surface and are very important globally in terms of world productivity - capturing sunlight energy and carrying out photosynthesis - and also in production of oxygen for the world's atmosphere. Previously diatoms were thought to be

completely harmless. Although less toxic than the dinoflagellate toxins, domoic acid from diatoms produces amnesic shellfish poisoning - a syndrome with highly damaging and distressing effects.

Toxic algae are a major problem in Japan, and are also present in many other countries including the Philippines, Brunei, Hong Kong, Papua New Guinea, North America, and Europe. Interest in the issue of introductions of microorganisms via ballast water increased significantly following the publication of scientific evidence that the exotic toxic dinoflagellate *Gymnodinium catenatum* present in Tasmania's coastal waters was most probably introduced through ballast water and sediment discharge. The presence of this phytoplankter in the Derwent and Huon estuaries in Tasmania has resulted in the periodic closure of commercial shellfish farms - both oyster and mussel - since 1986. In addition two other highly toxic species have turned up in Australia - in Adelaide and in Melbourne.

In addition to toxic dinoflagellates there are other potential impacts on aquaculture and native plant and animal communities. Ships could be introducing bacteria, viruses, and protozoans either in the water or sediment or within other organisms such as fish. Australia has been alerted to the potential impact of ballast water on their flora and fauna for some years and has been developing codes of practice. They began documenting introductions and tracking these to shipping patterns (e.g. striped goby, crab, shrimp - *Neomysis japonica*, Japanese sea bass). Early warnings of introductions of fishes in ballast water were published in the early and mid 1970s.

Recently a starfish normally restricted to the northern Pacific has been found in Tasmania. *Asterias amurensis* is believed to have been introduced by ballast water - and in a recently released report, the spread of this destructive starfish has been likened to a plague of rabbits (Anderson 1993). Both animals are "highly fecund and voracious eaters, with the capacity to inhabit large areas, causing damage to endemic and commercially valuable species". Every time a vessel takes on seawater in which starfish eggs and larvae are present there is the potential to disperse the animal to wherever the seawater is discharged.

Australia has been very active in responding to concerns about the introduction of exotic organisms through ballast water and sediment discharge, treating the problem as a quarantine issue, and actively pursuing adoption of an international approach to the problem through the Marine Environment Protection Committee of the International Maritime Organisation. In 1993 the IMO considered a survey that showed many countries are ignoring the IMO guidelines designed to reduce the risk of importing alien organisms (Anderson 1993). New Zealand has introduced voluntary controls for the release of ballast water and sediment in New Zealand waters. This is covered as a quarantine issue here under the control of Ministry of Agriculture - MAFQUAL staff. The quantities of ballast water released at New Zealand ports vary substantially between ports, and the composition varies enormously. In a six month period in 1992, for example, the peak of just over 60,000 tonnes of ballast discharged in Tauranga was made up from about 40 vessels whereas during the same period, the Port Chalmers quantity of 25,000 tonnes came from ballast released from the same vessel twice.

Are there any ways in which controls can be placed on ballast water introductions? At present, guidelines are voluntary because it is not known which is the most effective way of treating ballast water. There is no readily solution to the question of how to reduce to an acceptable level the risks associated with exotic organisms introduced with ballast water discharge. The issue is very complex because of the huge range of species involved, the large numbers of ports from which we receive the ballast water, and the number of ports which in turn receive the ballast water. In addition there are the interactions between factors that influence the introduction, establishment and subsequent impacts of an exotic species. However it is not impossible to find ways of reducing risks - and it is important that research be carried out with this aim.

In order to prevent or minimise exotic introductions the following options for control have been identified:-

- 1) at intake of the ballast water - e.g. ballasting in deep water, microfiltration;
- 2) removal of organisms prior to discharge of ballast and sediment - e.g. reballasting at sea, chemical and / or physical sterilisation;
- 3) non-discharge of ballast water and sediment - sediment retention and disposal outside territorial waters;
- 4) on-shore treatment of ballast water and sediment.

Unfortunately, the technology is not yet developed for these processes to occur economically. Reballasting at sea sounds logical - but it is not always possible. The ability of ships to reballast depends on a range of factors including sea conditions, the configuration of the ship's ballast tanks and pumps, and the size of the vessel. Because of hull stresses, the deballasting and reballasting in mid-ocean must be carried out very carefully in order to avoid structural damage. With increasing age of the vessel and with worsening weather conditions the potential for severe structural damage increases. All vessels are subject to stresses which increase the longer the vessel.

So far, no chemical agents have been found that are capable of killing dinoflagellate cysts without also causing environmental damage on discharge. Further physical techniques are being tested - ozone, UV light, heat treatment, filtration - as yet no clear option emerges. BHP is carrying out heat treatments to sterilise ballast water using the water that cools the ship's engines (Anderson 1993). On-shore treatment options would require the capacity for huge volumes of water and sediment - at the moment not a realistic prospect.

One of the puzzling aspects of the ballast water story is why the reports of exotic organisms have occurred only in the past 20 or so years, when seawater has been used as ballast for more than 100 years. One theory that has received some attention suggests that natural ecosystems around ports are destabilised by industrial pollution and the accumulation of nutrients such as nitrates and phosphates - and when foreign species are introduced into these highly modified environments some are able to flourish.

When we look at most parts of our terrestrial environment, the flora and fauna have been highly modified. The marine environment is much less modified - but it is also harder to see or measure the human impacts - particularly ones that are subtidal, chemical or microscopic. Sometimes the marine environment is protected from human impacts by the physical conditions, for example on high wave energy coasts. We know very much less about the marine environment and the changes that are occurring than we do about terrestrial systems. As the 1993 toxic algal bloom episode highlighted, we still know very little about our native phytoplankton flora and until we have a better grasp of what is present now we will not be in any position to recognise introduced species if they appear in our waters.

The movement of species around the country both deliberately and accidentally is a potentially important issue. At a time when *Undaria* was not long in New Zealand waters, it was growing luxuriantly on the Timaru dredge. This dredge is used in other harbours - and the potential for this to be a vector for the spread of this species is quite obvious. One of the outcomes of last summer's toxic algal blooms was the banning of movement of mussel spat attached to seaweed collected at Ahipara on 90 mile Beach to the Marlborough Sounds mussel farms. The reason for this was to limit the potential spread of toxic micro-organisms from one part of the country to another. Problems in the past few years with disease outbreaks in the Foveaux Strait oyster beds have led to bans on the movement of dredge oysters around the country. These kinds of local quarantine activities are important - but first the problem has to be identified. Mussels and

oysters are very important species to the fishing industry. Many other marine organisms have a much lower public profile and yet may be more important in the longer term.

Life in New Zealand as we know it would not exist if not for the exotic plants and animals we rely on - from our imported grasslands, orchards, horticulture, to our reliance in the foreign sheep, cow, deer, pig. There is no returning to a pre-settler New Zealand - but we do not want to acquire the marine version of *Clematis vitalba*. It is highly likely that the future will involve an expanding marine flora and fauna. The rate of expansion is not excessive at present but there needs to be an alertness to the potential problems and a willingness to invest in further research on our native flora and fauna so that we know what in fact is being threatened and something about the biology and ecology of our native communities and species.

References

- Adams, N.M. 1983 Checklist of marine algae possibly naturalised in New Zealand. *NZJB* 21:1-2.
- Anderson, I. 1993 Aliens slip through the international 'safety net'. *New Scientist*, 3 July 1993:5.
- Chilton, C. 1910 Note on the dispersal of marine crustacea by means of ships. *Trans. Proc. N.Z. Inst.* 43:131-133.
- Dinamani, P. 1971 Occurrence of the Japanese oyster *Crassostrea gigas* (Thunberg) in Northland, New Zealand. *N.Z.J. Marine & Freshwater Res.* 5:352-7.
- Dromgoole, F.I. 1975 Occurrence of *Codium fragile* subspecies *tomentosoides* in New Zealand waters. *N.Z.J. Marine & Freshwater Res.* 9:257-64.
- Druehl, L.D. 1973 Marine transplantations. *Science* 179:12.
- Foster, B.A. & Willan, R.C. 1979 Foreign barnacles transported to New Zealand on an oil platform. *N.Z.J. Marine & Freshwater Res.* 13:143-49.
- Francis, M.P. & Evans, J. (in press) Immigration of subtropical and tropical animals in north-eastern New Zealand. *Proceedings of the Second International Temperate Reef Symposium*. Conservation Sciences Publication. Department of Conservation, New Zealand.
- Hay, C.H. & Luckens, P.A. 1987 The Asian kelp *Undaria pinnatifida* (Phaeophyta: Laminariales) found in a New Zealand harbour. *N.Z.J. Bot.* 25:329-32.
- Hay, C.H. 1990 The dispersal of sporophytes of *Undaria pinnatifida* by coastal shipping in New Zealand and implications for further dispersal of *Undaria* in France. *Br.phycol.J.*25:301-13.
- Hughes, S. 1992 'Escaped' algae threaten Mediterranean ecosystem. *New Scientist*, 7 March 1992:7.
- Jones, M.M. 1991 Marine organisms transported in ballast water. A review of the Australian scientific position. *Bureau of Rural Resources, Bulletin* 11:1-48.
- Kirk, T. 1896 On the products of a ballast heap. *Trans. Proc. N.Z. Inst.*28:501-507.
- Luke, A. 1992 Alien weed keeps travelling west. *New Scientist*, 17 October 1992:8.
- Nelson, W.A & Adams, N.M. 1991 Distribution of the adventive seaweed *Colpomenia bullosa*. *N.Z.Bot. Soc. Newsletter* 26:12-13.
- Nelson, W.A & Duffy, C.A.J. 1991 *Chnoospora minima* (Phaeophyta) in Port Underwood, Marlborough - a curious new algal record for New Zealand. *N.Z.J.Bot.* 29:341-344.
- Parsons, M.J. 1982 *Colpomenia* (Endlicher) Derbes et Solier (Phaeophyta) in New Zealand. *N.Z.J. Bot.* 20:289-301.
- Powell, A.W.B 1976 On the considerable influx of warmwater molluscs that have invaded northern New Zealand waters within recent years. *Rec. Auckland Inst. Mus.* 13:141-66.
- Schaap, A. 1992 *Undaria pinnatifida*, blackberries of the sea? *Fishing Today* 5:18-19.