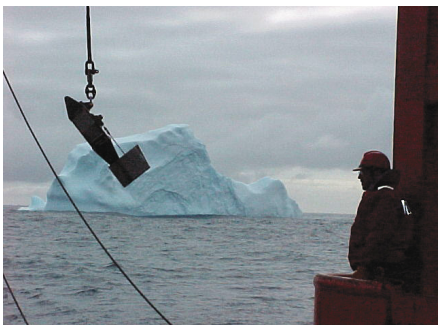
# Plankton survey uses old technology to monitor the future

In the mid 1920s, British scientist Sir Alister Hardy developed a radically new method for sampling plankton continuously, rather than taking spot samples using conventional plankton nets. Net sampling can often be inaccurate because of the unique patchy distribution and behaviour of plankton. Sir Alister designed the continuous plankton recorder to help study and to map these patches. He conducted the first trials of his 'Type I CPR' in Antarctic waters during the 1925-1927 voyages of RRS *Discovery* and RRS *William Scoresby.* Initial tows across the southern Atlantic Ocean brought mixed results, but a series of tows across Drake Passage, over nearly 300 nautical miles, produced the first continuous trace of Antarctic plankton patterns.



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Hardy later designed the more compact Type II CPR and established the North Sea and North Atlantic CPR survey, which is now the longest running marine biological survey, providing detailed synoptic plankton data for more than 70 years. Over that time the CPR has proven to be the most cost-effective method of repeatedly surveying large ocean areas quickly. The survey has been successful in detecting gradual changes in zooplankton and phytoplankton composition and distribution patterns, and the introduction and spread of non-indigenous species in the North Sea. In the mid-1980s the survey detected a significant regime shift in the plankton that may lead to catastrophic effects on the region's ecosystems and subsequently its fisheries. This shift happened in just one or two years rather than as a linear response to climatic or environmental change over several years.

Sixty-five years after the CPR was first trialled, the instrument returned to Antarctic waters when the Australian Antarctic Division initiated a CPR survey of the Southern Ocean. The purpose was first to map the patterns of biodiversity of plankton through the region, and then to use the sensitivity of plankton to environmental change as early warning indicators of the health of the Southern Ocean. That survey will also serve as reference on the general status of the Southern Ocean for comparison with other monitoring programs. Understanding patterns of variation in biological systems, both natural and those caused by climate change, has been an integral part of Australia's Antarctic research strategic plan. Plankton form the foundation of the Antarctic marine ecosystem and are thus the logical place to start such research.


*Above: Cutaway view of the internal mechanisms of the AAD-built CPR. Plankton are filtered by the collecting silk (shown in green) stretched across the tunnel. This is then met by the cover silk (red) before rolling into the preservation tank. Left: Deploying the CPR from RSV* Aurora Australis. *Bottom: Old and new side-by-side. An AAD-built Mk V CPR and a 1960s Mk II CPR (No. 122) pressed back into service.*




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CPR units were obtained from the Sir Alister Hardy Foundation, and trialled on RSV *Aurora Australis* during the ship's maiden voyage to Heard Island in July and August 1990. Trials continued in the sea ice zone during subsequent summer seasons. The units performed well enough but were easily damaged by ice, and during deployment or retrieval. In 1995, the Australian Antarctic Division instrument workshop and drafting team used a computer to designed a new 'Type II Mark V' CPR. The device was constructed from marine grade stainless steel rather than phosphor bronze as used previously. It was more streamlined then previous models, and internal recording cassettes were redesigned for easier loading and unloading of plankton mesh and preservative. The precision provided by computer control of machining meant that all new cassettes were interchangeable between external CPR bodies and had fully-interchangeable parts. But otherwise, the Mk V CPR differs little in overall design and performance from Hardy's original Type II.

The CPR looks like a Heath Robinson device but actually functions simply. It is a self-contained automatic sampler towed behind the ship at normal ship speed and can operate in nearly all sea conditions. As the CPR is towed along, water and zooplankton enter a small 1.25 x 1.25 cm aperture in the nose cone, which then expands into a wider collecting tunnel, slowing down the water flow. The plankton are then trapped between two bands of 270 µm mesh silk (6m long x 15 cm wide), loaded in a removable cassette. The silk and plankton 'sandwich' is wound on to a take-up spool inside a formalin preserving chamber, all driven by passing water turning an external propeller. Regardless of

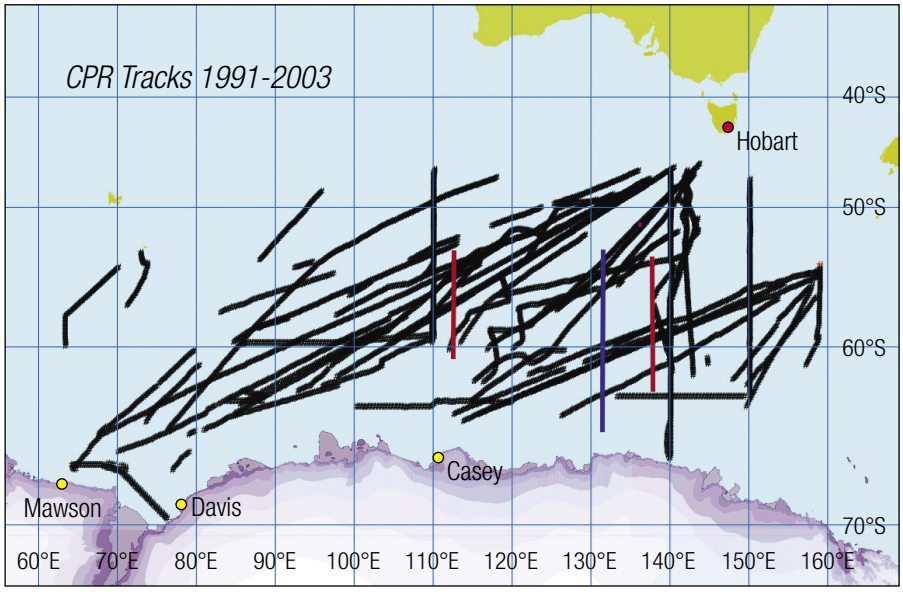
the speed of the vessel, the sheets of silk are advanced at a fixed rate of 1cm per nautical miles travelled. Each tow represents a 450 nautical mile track of continuous sampling. Back in the laboratory, each set of silks is unrolled and cut into sections representing five nautical mile samples. Plankton are then identified by microscope and counted.

The northern hemisphere survey has always relied on ships of opportunity such as cargo vessels and ferries, but the SO-CPR Survey uses research vessels which gives us access to a suite of oceanographic, meteorological and navigational data recorded continuously onboard. These data can be spliced with the CPR data, giving for each five-nautical-mile plankton sample the position and time of sampling, plus averaged environmental data such as water temperature, salinity, fluorometry (indicating chlorophyll concentration), light levels, and ultra-violet light levels.

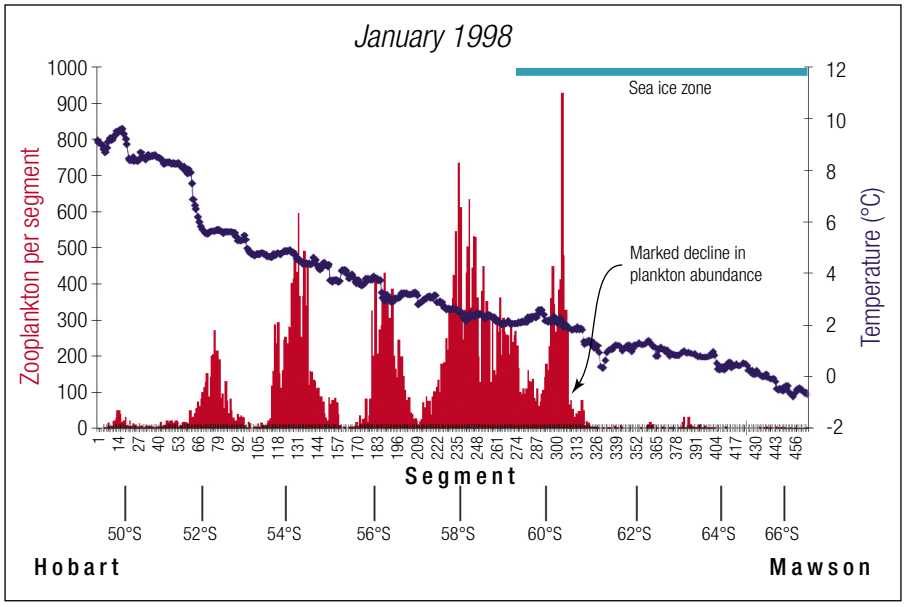
The principal survey area extends from 60°E to 160°E and south of about 46°S to the Antarctic coast – an area of more 14 million square kilometres or just under 30 percent of the Southern Ocean. CPRs are towed on all voyages of *Aurora Australis* when travelling to and from Antarctic stations and on dedicated marine science voyages, from early spring to autumn and occasionally in winter. Sampling has been done in all months except June. This sampling forms the core of the data, both geographically and temporally.

Since 1999, CPRs have also been towed from the Japanese icebreaker *Shirase* during its annual resupply of Syowa station. This takes advantage of the ship's fixed route and time schedule as a temporal reference for measuring long-term annual variability and to help interpret the Australian data. Tows have also been conducted on other Japanese research vessels opportunistically which has allowed hypotheses on spatially and seasonally variation to be tested (see 'Australia and Japan: two decades of collaboration in Antarctic marine science', p. 15).

Sampling was less intensive prior to 1997, during the development of the survey, and the redesigning, trialling and commissioning of the AAD machines. However, to date, the survey has already completed over 200 tows, providing more than 60,000 nautical miles (110,000 km) of records equivalent to 12,000+ samples for over 200 zooplankton species, and all coupled with environmental data. This number of samples would be impossible to collect using conventional net sampling.




*CPR tracks covered from 1991 to the end of the 2002-03 season.* Shirase *fixed tracks are shown in red. The four-ship survey of 140°E longitude in 2001-02 is shown in blue.*




*A typical series of CPR tows during a 2365 nautical miles (4380 km) run from Hobart to Mawson. Total abundance of zooplankton in each of the 460+ samples is shown in red with corresponding sea surface temperature averaged for the segment shown as a blue line. The typical decline in zooplankton south of latitude 60°S is highlighted.*

Typical CPR tows show very high abundance of zooplankton in the surface waters (top 20 m) of the permanent open ocean zone between the sea-ice zone and the Subantarctic Front, located not far south of Australia, Africa and South America. This is an area previously thought to have low plankton abundance, because it is low in nutrients (oligotrophic). By comparison, the surface waters of the sea ice zone have considerably lower species diversity and abundance. The demarcation between these areas of high and low abundances is consistently observed and quite abrupt, just south of 60°S latitude. This indicates the existence of a regular and perhaps new oceanographic event, as it cannot as yet be easily related to other known oceanographic features in the area.

Other north-south differences in abundance and species composition in the CPR tows are also regularly observed in relation to other frontal zones, such as the Polar Fronts and Subantarctic Fronts further north. Even subtle variation in zooplankton patterns have shown greater sensitivity in identifying oceanographic features that would normally only be readily identified through detailed profiling with oceanographic equipment.

The survey so far has identified new community and species distribution patterns, and we now have sufficient data to

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# Australian, Japanese scientists collaborate

The wide geographical coverage of the Continuous Plankton Recorder Survey (CPR) in the Southern Ocean is ideal for mapping biodiversity of plankton through the region. But with the survey extending over much of the year, changes in plankton patterns caused by geographical differences can be confused with those due to time. This complicates one of the objectives of the survey in identifying seasonal and long term changes in zooplankton patterns in response to environmental change.

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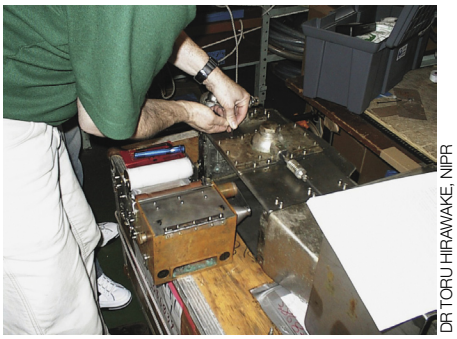
Fixed routine transects surveyed regularly would solve this problem, but a demanding Australian Antarctic shipping schedule has made this impossible.

By contrast, the Japanese icebreaker *Shirase* in servicing the Japanese Antarctic program's Syowa station has a fixed time schedule and route down longitude 110°E south from Fremantle each December. *Shirase* also follows the same return leg in February-March from Syowa, past Casey to 150°E, then north to Sydney. Japan's National Institute of Polar Research (NIPR) had established a long-term routine zooplankton monitoring program in 1972 with daily plankton net sampling across the Southern Ocean conducted at more or less the same time (noon) and location each year.

Some cyclic patterns linked with seawater temperature could be identified in the data, but it was clear that the small size of the net and the large distances between sites, 300 nautical miles (555 km), did not provide the required resolution for long-term mapping and monitoring of changes in plankton patterns in relation to the various oceanographic boundaries in the Southern Ocean. However, NIPR agreed that CPR tows from *Shirase* would benefit both national programs, enhancing their existing plankton monitoring program, while providing much needed fixed transects. A schedule of collaboration was agreed between Dr Graham Hosie, AAD, and Prof. Mitsuo Fukuchi, Director of the Centre of Antarctic Environment Monitoring at NIPR. Australian CPR units have been operating on Shirase since the 1999–2000 season.

The collaboration between Australia and Japan also provided the opportunity to occasionally use other Japanese vessels conducting plankton research around Antarctica – *Kaiyo Maru* (National Research Institute of Far Seas Fisheries), *Hakuho Maru* (Ocean Research Institute, Tokyo University), *Umitaka Maru* (Tokyo University of Fisheries) and *Tangaroa* (on charter to NIPR from NIWA, New Zealand). These vessels have supplied a large amount of routine data – nearly a quarter of the data has been supplied by Japanese vessels.



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*Above left: Crew of the* Shirase *ready to deploy the CPR during sea trials in the Sea of Japan. Above: Graham Hosie preparing the CPR for sea trials on* Shirase *in the Sea of Japan, September 1999.*

Use of these ships has also allowed a number of unique experiments to be conducted. The first of these was a set of almost simultaneous tows across the Antarctic Circumpolar Current in November-December 1999, along three widely spaced transects south of Africa (*Kaiyo Maru*), Fremantle (*Shirase*) and Macquarie Island (*Aurora Australis*) to test for similarities in zooplankton patterns across the frontal zones of the Antarctic Circumpolar Current. In theory, because the ACC flows uninterrupted around Antarctica, the species composition of zooplankton should be the same within any part of the current. The three-ship survey found the hypothesis to be true.

The complementary experiment of looking at change within a season along a single transect, conducted in November and March of the 2001–02 summer, involved CPRs towed repeatedly by four ships, *Aurora Australis, Hakuho Maru, Tangaroa* and *Shirase*, along longitude 140°E. A number of plankton assemblages were identified with strong north-south zonation in association with the various oceanographic fronts. While these fronts varied in position through the season, the composition and integrity of the plankton assemblages remained consistent relative to the fronts, and strongly correlated with temperature.

The third experiment produced perhaps the most interesting results so far. Later in the 1999–2000 summer *Kaiyo Maru* closely followed Sir Alister Hardy's April 1927 CPR transect across Drake Passage. We are still looking for Sir Alister's original raw data in order to make a full comparison, but an initial comparison with his published descriptions of the 1927 data suggests a major change in plankton patterns has occurred between 1927 and 2000.

There is no doubt that the collaboration between Australia and Japan has greatly improved the CPR survey with the additional tows. The survey would benefit further with additional fixed transects. Germany is now assisting the survey with tows from their research vessel *Polarstern* south of Cape Town in March–April 2004, and it is hoped that CPR tows will then become routine on all future *Polarstern* voyages. Other nations have expressed interest in joining the survey.

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start commenting on patterns of biodiversity in relation to the various oceanographic zones in the region, as well as seasonal and inter-annual patterns. We cannot yet identify longer term patterns or trends, but the northern CPR survey has shown that changes in an ecosystem can occur very abruptly when changes in environmental conditions reach a point that causes a species or group of species to suddenly flourish or decline, altering the ecosystem balance. Both northern and southern surveys have also proven the value of plankton as sensitive indicators of environmental patterns and the CPR as a useful tool for mapping the consequences of change in the marine environment.

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