# *Oceanography in Tasman and Golden Bays*

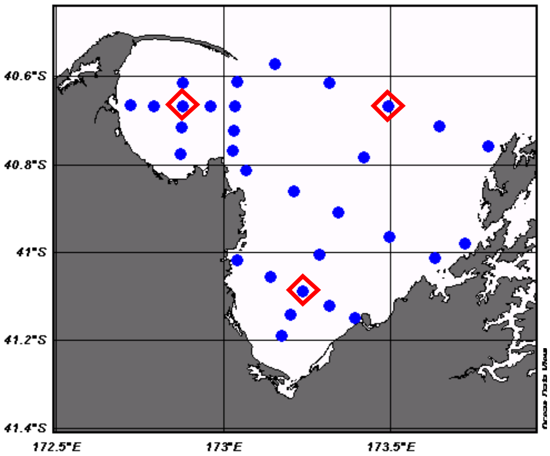
From summer 2001 to spring 2002, NIWA made four oceanographic voyages through Tasman and Golden Bays, on the research vessel *Kaharoa*. A major objective of the research was to understand the ecology of the phytoplankton that live in these waters.

Phytoplankton (free floating, single-celled marine algae) starts the marine food chain, by harnessing sunlight energy and nutrients to grow and reproduce[1]. This production supports feeding by animal plankton (zooplankton) and filter-feeding shellfish, and underpins aquaculture, fisheries and other ecological services within the Bays. Sometimes, blooms of certain types of toxic phytoplankton may occur[2]. Blooms of non-toxic algae can also be a nuisance, should they become so great as to cause reduced oxygen content in the water. These conditions can be caused by excessive nutrient runoff from land, but thankfully, such conditions do not presently occur in Tasman and Golden Bays.

Our major goal is to understand the drivers of phytoplankton production: what causes it to wax and wane; how it might change from year-to-year. In order to understand these ecological aspects of phytoplankton we need to understand how seasonal changes and other environmental factors - such as runoff from the surrounding land and mixing with the open ocean - affect their abundance and growth. Phytoplankton growth, like grass growth, is limited by a number of factors, including sunlight levels, nutrients and grazing by animals higher in the food chain[3], all of which must be studied to understand phytoplankton production.

In this article we summarise information collected during the *Kaharoa* voyages and provide a glimpse into our current understanding of how variation in oceanic processes affect phytoplankton ecology in Tasman and Golden Bays[4].

## The surveys and investigations



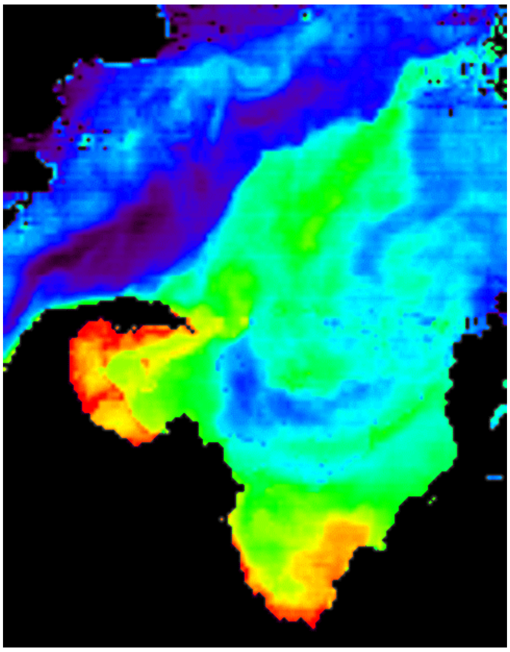

*Fixed sites (blue) were sampled during ship surveys on four seasonal visits. Instrument moorings (red) sampled continuously. Additionally, when possible, a towed instrument (Biofish)[5] was used to sample while underway between sites, to provide a detailed picture of spatial variability.*

The map shows that the *Kaharoa* voyages traversed Tasman Bay, Golden Bay and adjacent Cook Strait waters. This strategy was used because we expected that phytoplankton growth in the Bays would depend on interactions of Bay waters with water runoff from the adjacent land catchments as well as with more oceanic waters from Cook Strait.

*We collected water samples by using a set of plastic bottles attached to an instrument package and deployment frame - which can be lowered down through the water. The water bottles are closed electronically at the required depth. The instrument is then retrieved and the water processed on board the ship and in the laboratory. This instrument also collects data electronically to provide a water column profile of pressure (depth), temperature, salinity, light, water clarity and phytoplankton abundance (chlorophyll fluorescence).*

Although the ship sampling covered a wide area over an entire year, only a few days were sampled in each season. Because we knew that marine conditions could change rapidly between our ship visits, we also deployed instrument moorings[6] in key locations and used satellite measurements of sea surface temperature and ocean colour[7] to fill the gaps between the voyages.

Thus, our sampling strategy provided data at intervals of minutes, days and months, over the region.



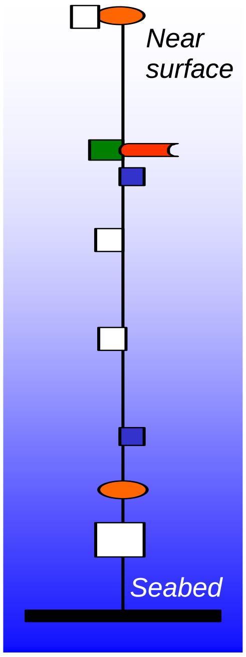
*Satellite image of chlorophyll, a photosynthetic pigment found in phytoplankton, and a measure of its abundance. High chlorophyll concentrations within the Bays are coded with red colour, decreasing through yellow and green to lowest values in blue. Land and cloud are black. Highest values in red may be overestimated (see text).*

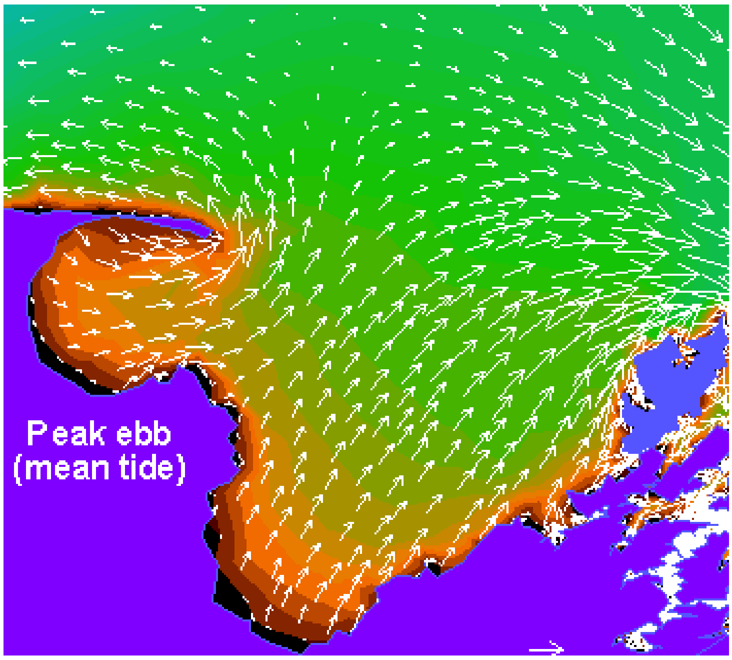
*In the image the D'Urville Current is clearly seen flowing to the northeast on the West Coast, and into northern Cook Strait. These satellite data are used courtesy of NASA MODIS project (http://modis.gsfc.nasa.gov) and were processed and visualised at NIWA, Wellington.*

Changes in phytoplankton occurring across the Bays are seen in the ocean colour satellite image. The colour detected by satellite arises from the chlorophyll pigment within the phytoplankton, but is also affected by other dissolved and particulate material found in coastal waters. NIWA is developing the means to separate these signals, in its remote sensing research in Tasman and Golden Bays. Satellite remote sensing is a powerful tool we are using to understand how the phytoplankton changes in the Bays, daily, seasonally and annually across the region.

The satellite image displays the complexity of Tasman and Golden Bays in relation to waters further offshore. The Bays are bathed in waters from Cook Strait, originating largely from the D'Urville current[8] from the West Coast - although on occasion waters may enter from the eastern Strait. Thus, it is important to determine the linkages of the Bays to oceanic waters for a complete understanding of their oceanography. For this reason, we are using our mooring data and data collected at the sampling sites to calibrate computer model simulations of circulation between the Bays and Cook Strait[9].

**Instrument moorings** **Computer modelling**

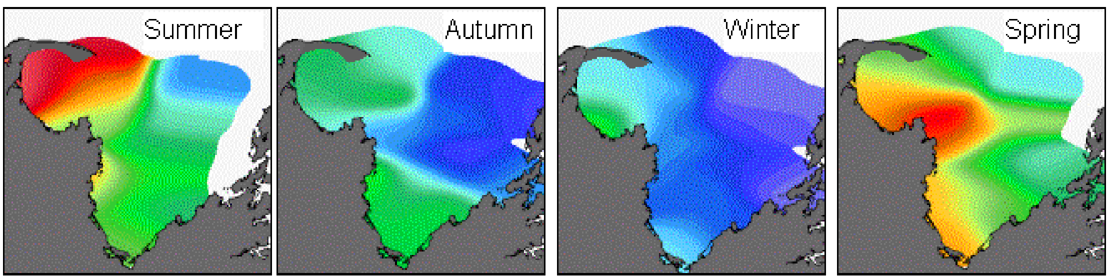



*Data from instrument moorings provide calibration for computer circulation simulations – a cornerstone for understanding and predicting the physical and biological properties of these Bays. Instruments on the moorings measure temperature, salinity, tide height and currents. The computer simulation shows the interaction between Golden Bay, Tasman Bay and Cook Strait waters during the change between high and low tide.*

## Seasonal changes

In this article we focus on the seasonal changes of phytoplankton in the Bays, that is, how the growth of phytoplankton is affected by sunlight levels and the vertical mixing of the water and nutrients, as the season's progress.



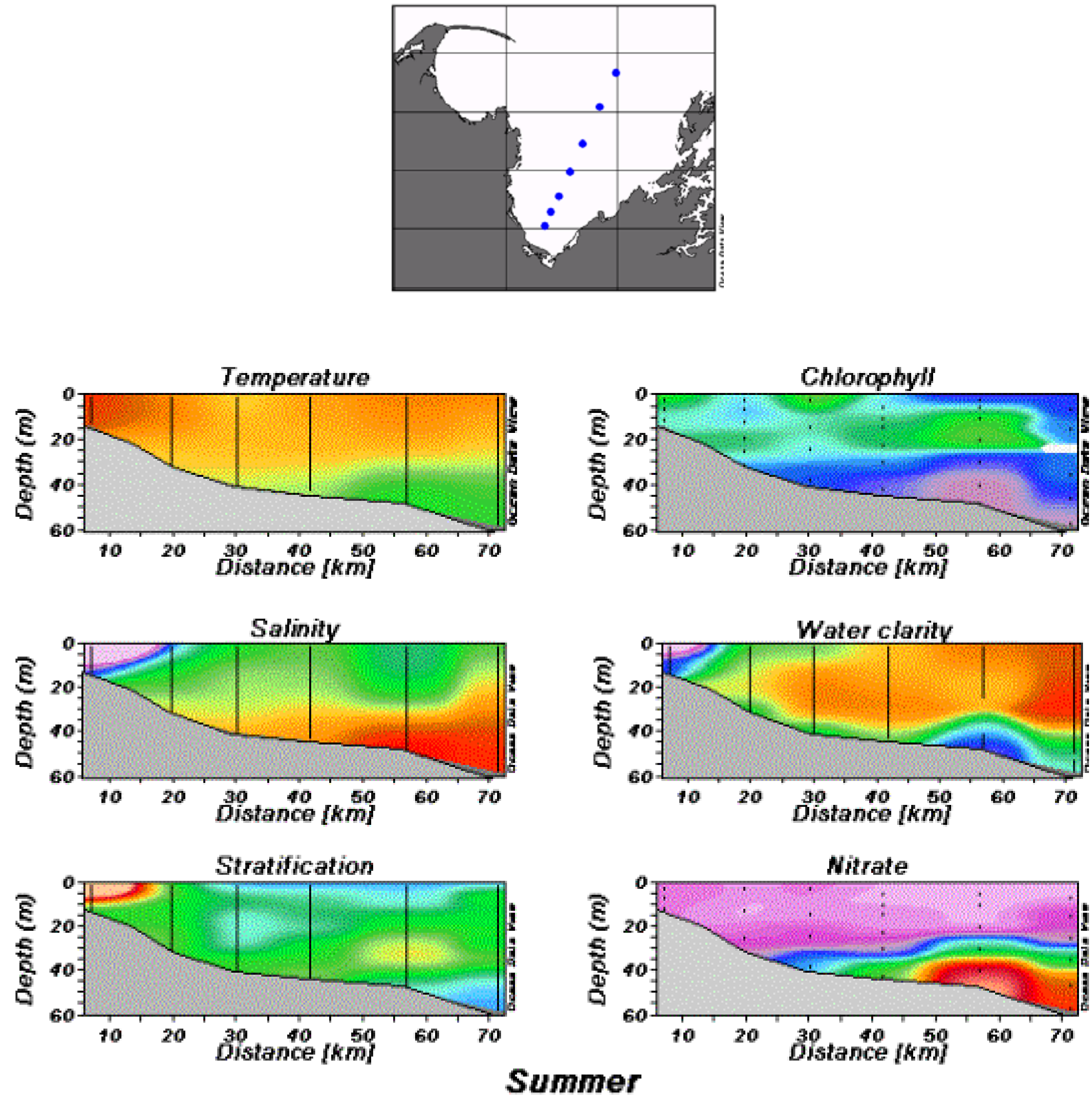

*Fixed station maps of chlorophyll (phytoplankton abundance) across the Bays and out to Cook Strait, for summer, autumn, winter and spring. The colours portray average chlorophyll abundance from near the surface to the seabed, with low abundance values in blue, increasing through green and yellow, to highest values in red.*

These maps of chlorophyll pigment provide an insight into the seasonal changes in phytoplankton. Summer and spring had the highest amounts of phytoplankton, and autumn and winter the least. As described next, it is the seasonally varying amounts of light, vertical mixing and nutrients that cause these changes. We focus here on Tasman Bay, but many of the principles illustrated also apply to Golden Bay.

**Summer**

With the summer sun high in the sky, there is plenty of light for phytoplankton growth in Tasman Bay. The sunlight also heats the surface water, making it more buoyant compared to bottom waters. When this effect is combined with dilution from the less dense freshwater from land and river flows, the waters become layered, or stratified. This is shown in the figure below, in which stratification values are highest throughout the middle and upper water depths. The layering slows the mixing of the algal cells between shallower and deeper waters, and ensures that the algae remain in the shallower water layers where light levels are ideal for growth. Thus, summer chlorophyll, and the phytoplankton it represents, is abundant across the entire bay out to Cook Strait.

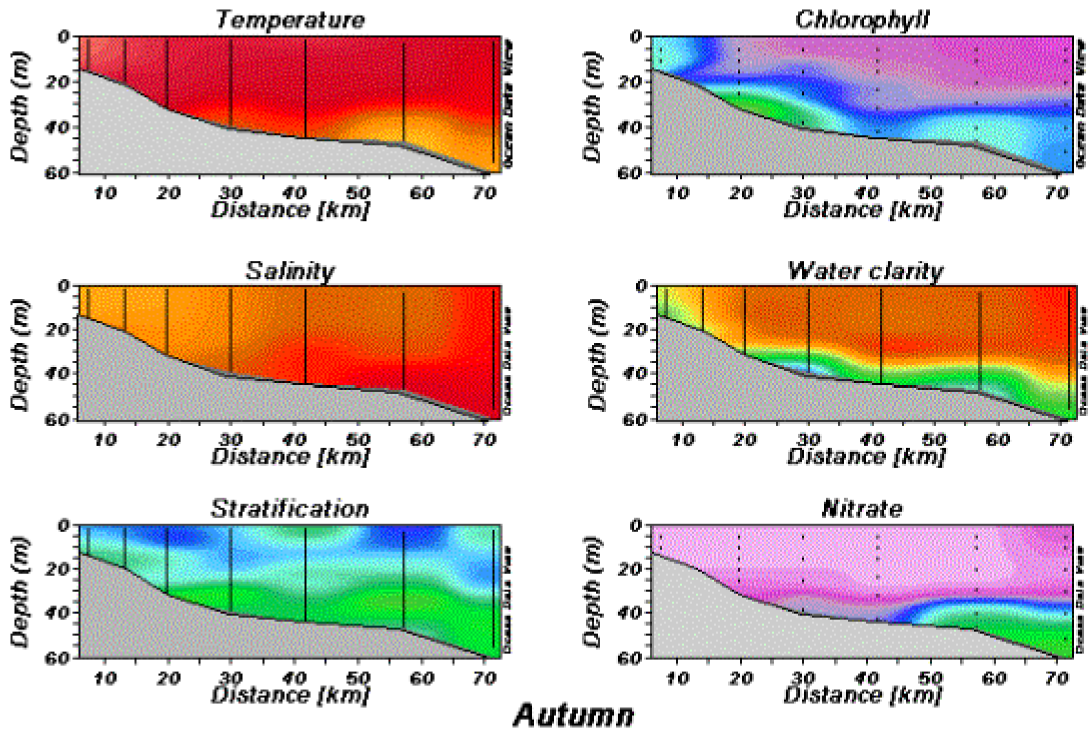
It is not only good light conditions that make for the strong summer growth. Although light is required to drive photosynthesis, chemical nutrients - especially nitrate - are also required. Nitrate is the most important fertiliser for new phytoplankton growth in the Bays. Other nutrients are important but they are usually abundant enough most of the time to not affect growth[10]. In summer, phytoplankton in the upper water uses the nitrate rapidly so that eventually it becomes depleted, and must be replaced, for phytoplankton to continue to grow. Much of the nitrate re-supply comes from the deeper waters of the outer Bay and Cook Strait, mixed up through the water and into the Bay, to fertilise the phytoplankton growing there. Although freshwater entering through rivers at the head of the Bay also supplies nitrate to the surface layer, its chief role in promoting phytoplankton may be in supporting the stratification[11]. This is a subject of our continuing research.




*Summer (December) water conditions in Tasman Bay. The data are from the sites in the top map, and are shown as 'slices' down through the water, from inner Tasman Bay out to Cook Strait. The panels display temperature, salinity, stratification, chlorophyll (phytoplankton) and nitrate. Colours show values of these quantities, increasing from purple and blue, through green and yellow, to highest values in red (other seasonal figures, below, follow the same layout). In this summer figure, relatively high values of stratification and abundant deepwater supplies of nitrate combine to support strong phytoplankton growth, as indicated by the high values of chlorophyll.*

## Autumn

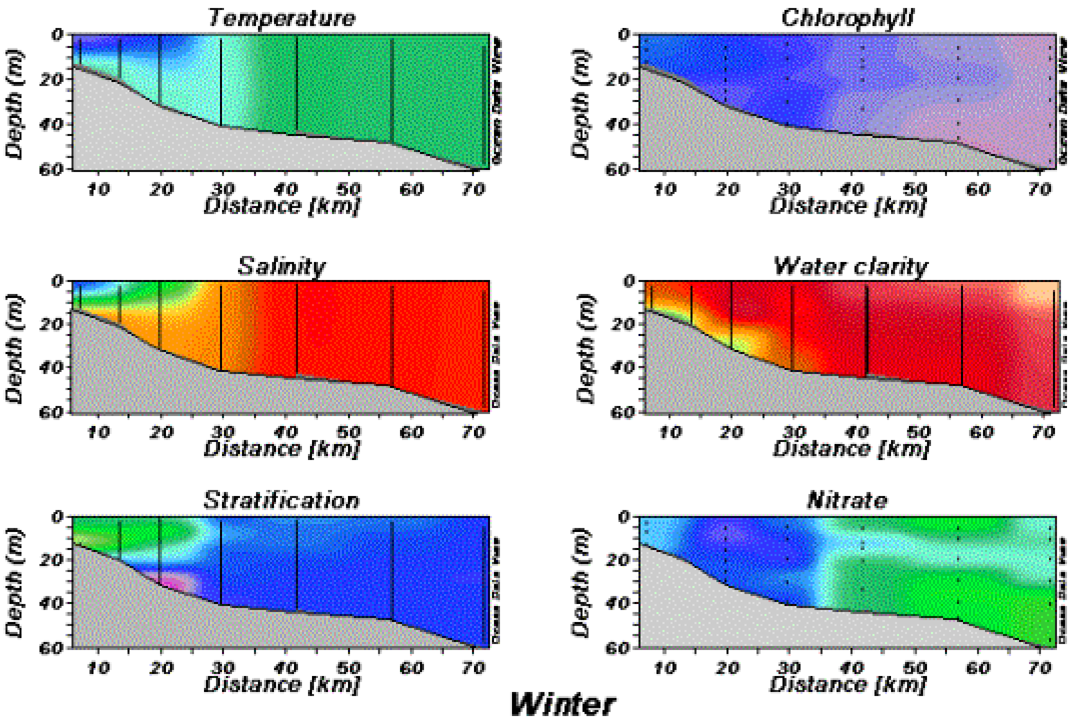
By autumn, things have changed. Low river flows over late summer, combined with deep mixing of surface heat, have caused the upper water to lose its salinity and temperature stratification. Greater stratification is now found close to the bottom and it is only there that phytoplankton have the right conditions for growth - near to the supply of nitrate near the seabed. Although increased water clarity allows this growth at depth, the phytoplankton may be growing more slowly than in summer due to the low light levels. Nitrate levels have reached their annual minimum, after being used up in the summer growth.




*In autumn (March), stratification has weakened and is greatest deeper in the water. The phytoplankton is also deep, near its nitrate supply, but it can grow there because surface waters are clear.*

## Winter

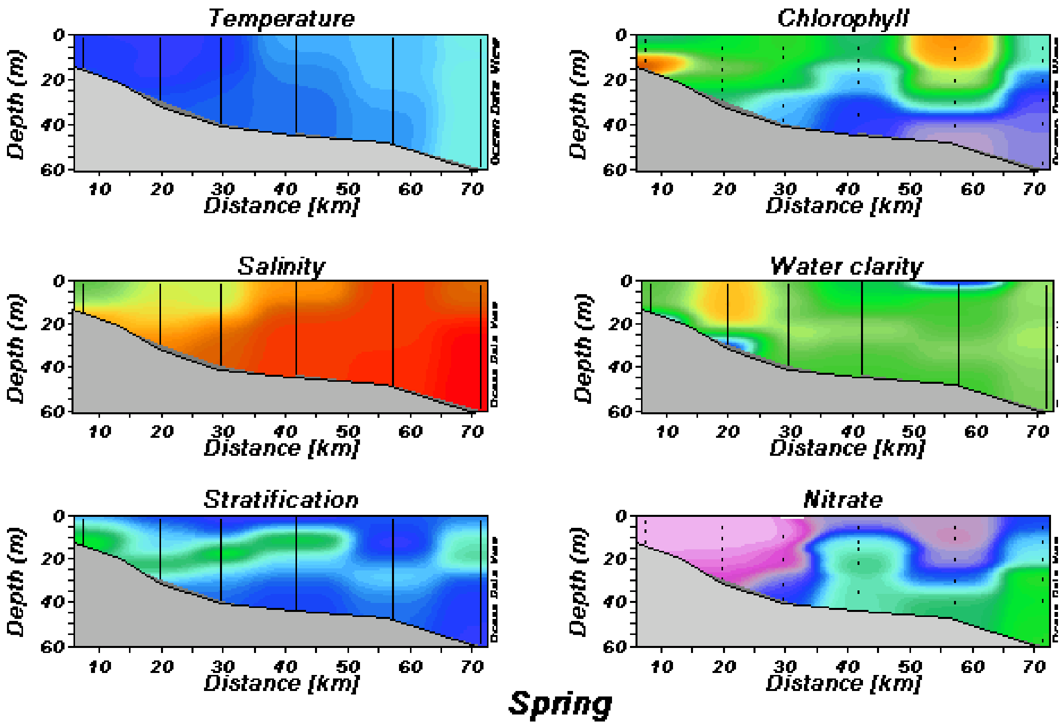
In winter, stratification is almost entirely broken down due to low thermal input and strong winds - which deeply mix the water column. The Bay is 'recharged' with nutrient, through vigorous mixing and exchange with deep Bay waters and Cook Strait. But, although nutrients are mixed all the way to the surface, the low winter light levels and deep mixing result in insufficient average light conditions for growth of phytoplankton. Thus, like a pasture, the Bay has been ploughed and laid fallow by the winter conditions.




*In winter (July), waters are deeply mixed and stratification breaks down, although some stratification is maintained near river inputs, inshore. Nutrients in the upper water have been replenished by the deep mixing, but low winter light levels and the mixing keep phytoplankton from growing. Phytoplankton abundance is at the annual minimum.*

## Spring

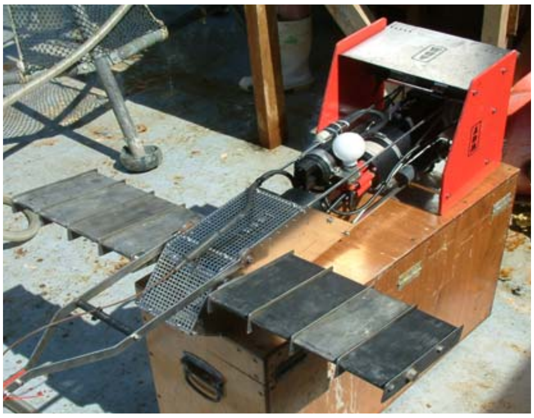
In spring, the sun is moving higher in the sky, heat is added back to the upper water column and stratification becomes more dominant again. This lets newly germinated phytoplankton linger in the surface layers, near the strengthening light. The water has been charged with abundant nitrate from the winter mixing, providing ideal conditions for growth and resulting in a phytoplankton bloom. Thus begins the spring and summer phytoplankton growth season, which supports the zooplankton and other populations of animals in Tasman Bay, such as scallops and farmed mussels.




*In spring (September), increasing stratification allows phytoplankton to bloom in the nutrient-rich conditions caused by winter mixing. The nitrate, however, is already starting to get used up and must be replaced by steady mixing up through the water to maintain the phytoplankton growth over spring and summer.*

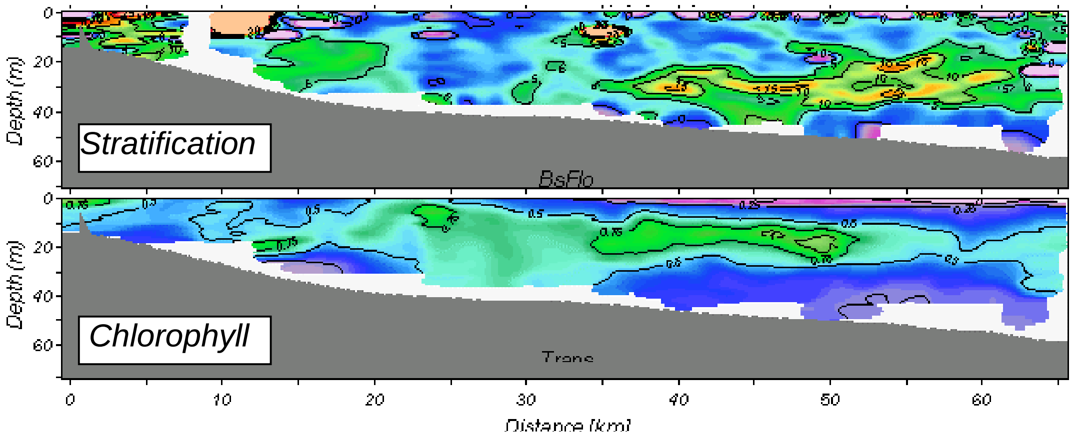
## Differences across and between the Bays

In addition to changes through time, we are also interested in seeing the detailed changes in space across the region. By using 'Biofish' - a towed instrument which 'yo-yo's' up and down through the water collecting data while the ship steams between sites[5], we have obtained detailed maps of water properties and compared them with the more widely-spaced data from the seasonal sampling sites. These detailed plots - equivalent to 380 vertical samples over the 70 km transect - confirm that the less detailed data collected at our seasonal sites across the bays (see the 'summer' plots, above) are providing a realistic picture of the general spatial patterns in stratification and phytoplankton abundance.

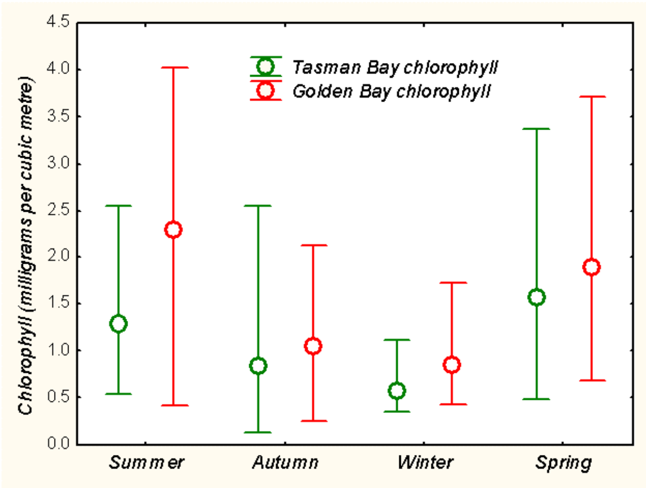


*The 'Biofish' (left) collects data that shows the stratification and chlorophyll patterns in great detail (below), from inner Tasman Bay out to Cook Strait.*

*These plots can be compared with the summer voyage plots given earlier in this article, using data collected at the individual sampling sites.*

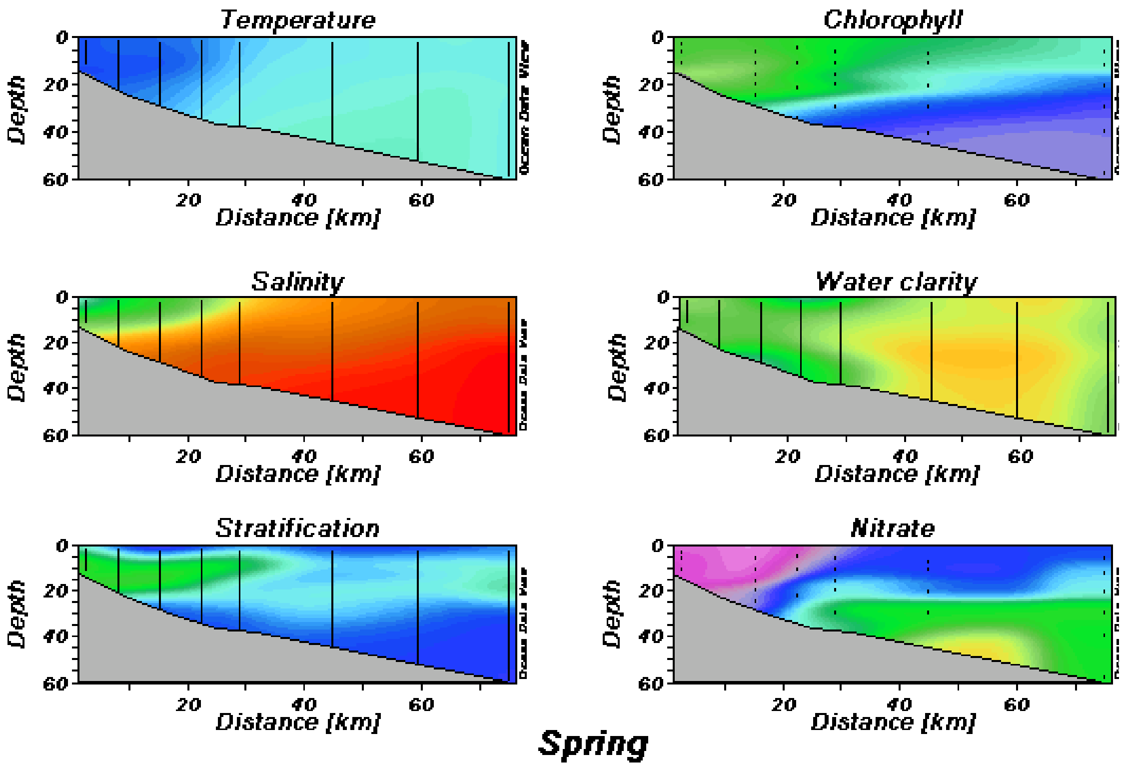



By and large, seasonal phytoplankton abundance patterns in Golden Bay are similar to those in Tasman Bay, although as seen in the satellite image presented earlier, the amount of phytoplankton in Golden Bay is higher. When we analyse the seasonal data for all stations sampled in each bay (line graph below) we indeed see that more chlorophyll occurs in Golden Bay at most times of year. This is also seen when we look at data on a transect through Golden Bay (panels below), in the same way as we did earlier for Tasman Bay. Although there are similar patterns in stratification and nutrients chlorophyll is more abundant than in Tasman (in this case, in spring). An important part of future work will be to understand why the Bays differ in some aspects but not others.




*Average chlorophyll concentrations (phytoplankton) in each season, in Tasman Bay (green circles) and Golden Bay (red circles). The bars show the minimum and maximum values in each bay. Golden Bay always had more chlorophyll, and in spring and summer some very high values were found in some places.*

*In the graphs below, spring data from inner Golden Bay out to Cook Strait show that, like Tasman Bay, stratification and near-bed nitrate supplies supported the spring bloom.*




## Further work

We have seen that productive conditions depend on what is happening within the Bays and their interactions with Cook Strait and river waters. An important aspect is the interaction of stratification, nutrient supply and phytoplankton growth. We expect that our seasonal surveys over the 2001-2002 year in Tasman and Golden Bays have captured ‘snapshots’ of conditions, which will change both within and between years. These dynamics may cause short - term events that may be missed by seasonal surveys such as ours. For example, other studies have documented phytoplankton increases in inner Tasman Bay in autumn[11]. This occurs when nutrients are mixed into the upper waters by the seasonal breakdown of stratification, but when light is still sufficient to generate growth. We expect that we will resolve these detailed patterns, by studying our mooring and satellite data.

To gain further understanding, in our continuing work on the oceanography we are combining our ship-based measurements and satellite data with instrument-mooring and climatic information from national databases, to develop computer-based current-flow and water-quality models covering the Bays and greater Cook Strait area. Such modelling is a powerful way to understand and predict changes in productivity of the Bays and their susceptibility to human-induced change.

As part of the data analysis and modelling effort, we will investigate how variability in factors such as wind strength and direction and river flows (which in turn are related to climatic variation) impact key oceanic processes such as deep mixing and stratification and thus affect nutrient and light supply to phytoplankton, and its availability to aquaculture and other fisheries. In turn, aquaculture and other human influences such as nutrient runoff may also affect these systems. These are subjects of ongoing research within three research programmes at NIWA, funded through the Foundation for Research Science and Technology[12]. Through these continuing observations and modelling studies we will gain understanding of natural and human influences on the ecology of Tasman and Golden Bays.

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**Further reading**

The following articles may be of further interest and are available on the NIWA website or in public libraries.


1. Factors affecting phytoplankton: Gall, M.; Ross, A.R.; Zeldis, J.; Davis, J. (2000). Phytoplankton in Pelorus Sound: food for mussels. *Water & Atmosphere* 8(3): 8-10. http://www.niwa.co.nz/pubs/wa/08-3-Sep-2000/phytoplankton.htm

2. Satellite ocean colour tracking of harmful algal blooms: Chang, H.; Richardson, K.; Uddstrom, M.; Pinkerton, M. (2005). Eye in the sky: tracking harmful algal blooms with satellite remote sensing. *Water & Atmosphere* 13(2): 14-15. http://www.niwa.co.nz/pubs/wa/13-2/bloom

3. Zooplankton seasonality: Zeldis, J., Pinkerton, M. 2000. Seasons of size in the Oceans. *Water and Atmosphere* 8(3): 11-12. http://www.niwa.co.nz/pubs/wa/08-3-Sep-2000/seasons.htm

4. Climate variability and effects on oceanic processes: Zeldis, J.; Gall, M.; Uddstrom, M.; Grieg, M. (2000). La Niña shuts down upwelling in northeastern New Zealand. *Water & Atmosphere* 8(2): 15-18. http://www.niwa.co.nz/ncces/articles

5. Biofish applications: Gall, M.P. (2002). Let's get biophysical! - with BIOFISH. *Water & Atmosphere* 10(4): 13-15. (http://www.niwa.co.nz/pubs/wa/10-4/biofish).

6. Mooring instruments and uses: Nodder, S., Chiswell, S., Boyd, P., Pinkerton, M., Greig, M. (2005). Biological pumps: does the ocean inhale or exhale? *Water & Atmosphere* 13(2): 18-19. http://www.niwa.co.nz/pubs/wa/13-2/pump

7. Applications of ocean colour in New Zealand waters: Pinkerton, M.; Richardson, K.; Boyd, P. (2001). Ocean colour offers new insights into New Zealand's upper-ocean ecosystem. *Water & Atmosphere* 9(1): 17-18. http://www.niwa.co.nz/pubs/wa/09-1/colour.htm

8. Ocean currents and how determining them are important to understanding the functioning of Bays: Carter, L. (2001). Currents of change: the ocean flow in a changing world. *Water & Atmosphere* 9(4): 15-17. http://www.niwa.co.nz/pubs/wa/09-4/currents

9. Computer circulation modelling: Rickard, G., Hadfield, M. (2004). Forecasting ocean 'weather'. *Water and Atmosphere* 12(4): 24-25 http://www.niwa.co.nz/pubs/wa/12-4/forecast

10. Tasman bay nutrients and productivity: Mackenzie, A.L., Gillespie, P.A. (1986). Plankton ecology and productivity, nutrient chemistry, and

hydrography of Tasman Bay, New Zealand, 1982-1984. *New Zealand Journal of Marine and Freshwater Research* 20: 365-395.

11. Stratification and phytoplankton: Mackenzie, L., Adamson, J. (2004). Water column stratification and spatial and temporal distribution of phytoplankton biomass in Tasman Bay, New Zealand: implications for aquaculture. *New Zealand Journal of Marine and Freshwater Research* 38: 705-728.

12. To go to NIWA centres and relevant research programmes supporting Tasman and Golden Bay research see: http://www.niwa.co.nz/ncco/ , http://www.niwa.co.nz/ncfa/ and http://www.naturalhazards.net.nz/ .