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Visualising nutrients and phytoplankton in the Hauraki Gulf Marine Park using GIS

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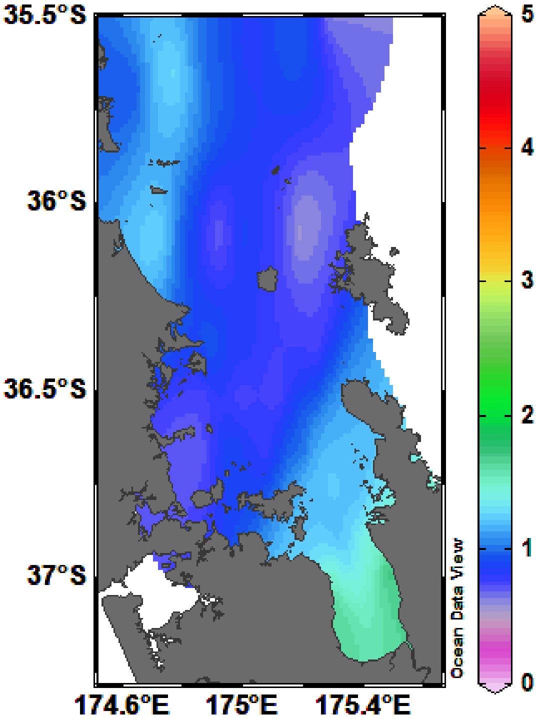

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Cover image: Interpolated map of near-surface chlorophyll (mg/ m^3) in Hauraki Gulf Marine Park averaged across all seasons.

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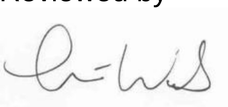
Reviewed by



Chris Woods

Approved for release by

Charles Pearson

Executive summary

This report presents geographic information system (GIS) layer data for chlorophyll-*a*, and dissolved inorganic nutrients (nitrate, ammonium and phosphorus) over the spatial extents of NIWA surveys conducted in the Hauraki Gulf Marine Park region over the last 17 years. Chlorophyll-*a* is a cellular constituent used by marine phytoplankton for photosynthesis and indexes phytoplankton abundance, and dissolved nutrients are key nutrients phytoplankton use to fertilise their productivity. The GIS layers are provided for those stakeholders in the aquaculture industry and other users who wish to explore the data available from NIWA surveys, to get more information about spatial and seasonal variability of productive conditions in the Hauraki Gulf Marine Park.

We provide GIS layers (at approximately 1km^2 pixel resolution) for chlorophyll-*a* and nutrient concentrations from the Firth of Thames to the continental shelf north of Hauraki Gulf. These are presented seasonally (winter, spring, summer, autumn) for near-surface and deeper water column layers.

We also plot these properties through the water column by depth, across the region. This is accompanied by descriptions of patterns in the data, allowing a non-expert user to understand the seasonal and spatial changes. We describe how nutrient inputs from upwelling, rivers and local recycling combine with seasonal cycles of temperature, freshwater input and light, to control phytoplankton levels.

We document the data using the ISO standard through ARC GIS following NEGIS metadata guidelines.

1 Introduction

1.1 Productivity at the base of the food web, in the Hauraki Gulf Marine Park

The primary production of phytoplankton is a cornerstone of the marine ecosystem in the Hauraki Gulf Marine Park. Phytoplankton use nutrients and light to create their organic structures through photosynthesis, thereby fuelling the aquatic food web and sustaining all life from viruses to whales. Ocean surveying by NIWA has revealed how nutrient inputs from upwelling, rivers and local recycling combine with seasonal cycles of temperature, freshwater input and light, to control phytoplankton levels.

This report presents geographic information system (GIS) layers and associated metadata for chlorophyll-*a*, and inorganic dissolved nitrogen and phosphorus over the spatial extents of NIWA surveys conducted in the Marine Park region. Chlorophyll-*a* is the main pigment that marine phytoplankton use for photosynthesis, and dissolved nutrients (nitrate and ammonium, as well as phosphorus) are key nutrients they utilise. The nitrogenous nutrients, in particular, are critical because their abundance typically sets the upper levels of phytoplankton yield that can be achieved in the coastal marine ecosystem, as well as strongly affecting phytoplankton growth rate.

The GIS layers are provided for those stakeholders in the aquaculture industry and other users who wish to explore the data, to get more information about spatial and seasonal variability of productive conditions in the Hauraki Gulf Marine Park.

1.2 Scope

We provide GIS layers (at approximately 1km^2 pixel resolution) depicting chlorophyll-*a* (chl-*a*) and phytoplankton dissolved nutrient (nitrate, ammonium and reactive phosphorus) concentrations from the inner Firth of Thames, through the Hauraki Gulf, to the continental shelf edge near the northern boundary of the Marine Park. These are presented seasonally (winter, spring, summer, autumn) for near-surface and deeper water column layers.

We also present seasonal ‘slice’ diagrams depicting nutrient and chlorophyll concentrations that ‘cut’ through the water column by depth, along a transect line extending from the inner Firth to the shelf edge. This is accompanied by descriptions of patterns in the data, allowing a non-expert user to understand the seasonal and spatial changes.

We document the data using the ISO standard through ARC GIS following NEGIS metadata guidelines.

2 Data acquisition and selection

The Conductivity/Temperature/Depth (CTD) sampling equipment used for data acquisition is shown in Figure 2-1. As it is lowered through the water column, its electronic probes relay data on temperature, salinity, oxygen and light and phytoplankton fluorescence levels, and its bottles capture water at various depths for sampling of phytoplankton, nutrients and other water parameters for laboratory analysis. In this work, we use data from 16 of the NIWA voyages made across the region over the last 17 years, funded by MBIE and its predecessors (FRST, MSI).

Figure 2-1: The Conductivity/Temperature/Depth (CTD) device about to be deployed from the stern of NIWA RV *Kaharoa*. It is lowered though the water and used to sample numerous water column parameters using the electronic sensors at the base of the package, and by capturing water in the bottles for later laboratory analysis**.**

Nutrient and chlorophyll values are provided in this project as interpolated layers in GIS format. The interpolations are based on the data values at the sampling stations most commonly occupied across the region, averaged for each of the four seasons. The layers and underlying station locations are plotted in Appendix A (Figure A-1 and Figure A-2), and an example of their accompanying metadata is provided in Appendix B, including information on interpolation methods.

The GIS horizontal spatial coverage extends from the inner Firth of Thames to the outer continental shelf beyond the Poor Knights Islands and its vertical coverage is for two depth bands in the water column. The first depth band averages data from the upper 15m and describes 'near-surface' conditions (this includes the entire water column for the shallowest stations in the inner of Firth of Thames). The second band averages data for the deeper water column, from 16m down to a maximum of 50m. This band extends to the bottom over much of the survey area, from the mid-Firth to just north of Little Barrier Island, and into mid-water in deeper areas further north. It does not include the inner Firth and other shallow areas of the Hauraki Gulf coastline because those areas are shallower than 16m (these areas are masked out in the GIS layer data).

Data were selected on the condition that their surveys extended over as much of the Hauraki Gulf Marine Park as possible. They were collected on ‘grids’ of stations surveyed over 1996–2012 (Figure 2-2 and Table 2-1). The surveys varied somewhat in their research objectives and hence had varying spatial distributions, falling into four groups (Table 2-1). Surveys were apportioned seasonally within these groups, except for the first group which did not have a winter survey, and the fourth group for which winter and summer surveys have not yet been carried out. Overall, within each of the four seasons, there were between two and five surveys (Table 2-1).

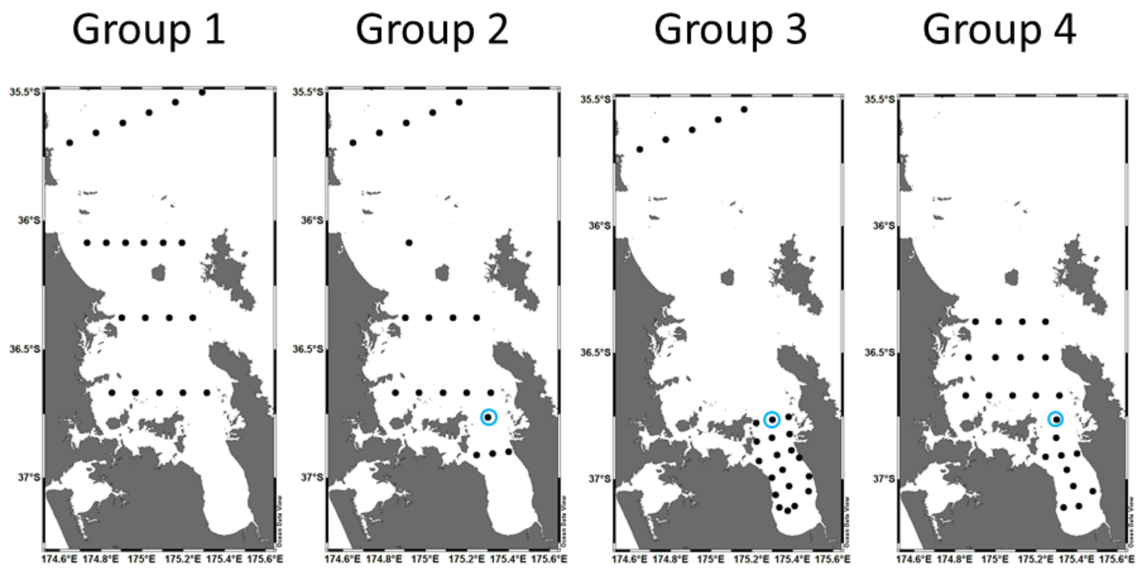


Figure 2-2: Distributions of sampling stations within each group of grid surveys, sampled 1996–2012. Survey time periods are given in Table 2-1. Time series station SA03 (see text) is indicated by the blue circle.

CTD data used here were for temperature, salinity, oxygen and phytoplankton fluorescence, averaged for each meter of depth. Water samples for nutrients and chlorophyll were usually collected at six depths (or up to 12 depths in Group 1), with somewhat closer sample spacing in the upper 80m of the water column, than below. Very shallow inner Firth stations (5–10m depth) had as few as two water samples per cast.

The station selection excluded the intensively-sampled time series station SA03 (Figure 2-2) located at the seaward Firth of Thames, except when that station was included within a grid survey. This excluded 37 other voyages which occupied SA03 between 1998 and 2013.

Table 2-1: Descriptions for grid surveys sampled 1996–2012 for each survey group, voyage ID and season Comments give numbers of bottle samples taken on casts in the surveys for nutrients and chlorophyll. For the two transects crossing the central Hauraki Gulf in group 2, chlorophyll values were estimated from phytoplankton fluorescence, using linear relationships of CTD fluorescence to extracted chlorophyll, using Firth and shelf station data from those voyages.

Group	Season	Voyage ID	Comments
1 (1996-97)	Spring	KAH9614, TAN9612	Nut and chl: 6–11 per cast
	Summer	KAH9617	Nut and chl: 6–11 per cast
	Autumn	TAN9702	Nut and chl: 6–11 per cast
	Winter	Not surveyed	
2 (2000-01)	Spring	KAH0010	Nut and chl: 6 per cast; Gulf chl estimated from fluorescence; r^2=0.71
	Summer	KAH0013	Nut and chl: 6 per cast; Gulf chl estimated from fluorescence; r^2=0.82
	Autumn	KAH0105	Nut and chl: 6 per cast; Gulf chl estimated from fluorescence; r^2=0.66
	Winter	TAN0110	Nut and chl: 6 per cast; Gulf chl estimated from fluorescence; r^2=0.86
3 (2002-03)	Spring	KAH0309	Nut and chl: 2–6 per cast, depth allowing
	Summer	SEA0210, KAH0310	Nut and chl: 2–6 per cast, depth allowing
	Autumn	KAH0303	Nut and chl: 2–6 per cast, depth allowing
	Winter	KAH0307	Nut and chl: 2–6 per cast, depth allowing
4 (2009-12)	Spring	KAH1209	Nut: 2–6 per cast, depth allowing; chl sampled only near surface and near bottom. Transect S of Kawau Island not sampled.
	Summer	Not yet surveyed	
	Autumn	KAH0902, KAH1002	Nut and chl: 2–6 per cast, depth allowing, except chl sampled only at SA03 in KAH0902
	Winter	Not yet surveyed	

3 Seasonal patterns

To aid the GIS user's understanding of the seasonal patterns of productivity and nutrients in the Marine Park region, we provide the description below. Figure 3-1 and Figure 3-2 show data values interpolated as vertical sections through the water column, from the inner Firth to the shelf edge near the northern boundary of the Marine Park, from the surface to a maximum depth of 100m. These indicate the following seasonal patterns and dynamics:

Spring

1. In spring, water **temperatures** are low, from previous winter cooling. Temperature has an upward-sloping pattern extending from the deeper shelf waters into the Gulf. This is caused by upwelling, driven by westerly winds which are common over New Zealand during the spring equinoxial period.
2. **Nitrate** nitrogen is abundant in the deeper waters of the shelf and Hauraki Gulf and is brought onto the shelf by the upwelling.
3. Low **salinity** in the Firth of Thames indicates river flow into the Firth.
4. The nitrate from upwelling and river input fertilises phytoplankton production, indicated by the elevated levels of **chlorophyll** in the upper water column across the region. The active phytoplankton growth uses up **nitrate** as fast as it is supplied, accounting for the low nitrate levels in the upper water column. This means that nitrate supply is limiting the growth of phytoplankton.

Summer

1. In summer, cool water **temperatures** on the shelf and in the Gulf indicate continued upwelling, bringing high amounts of **nitrate**. This water enters the inner Gulf near the seabed, extending into the Firth.
2. Summer warming and river input causes surface waters of the inner Gulf and Firth to become stratified, or layered, with warmer, lower **salinity** and **density** water overlying cooler, higher salinity and density water.
3. Another form of nitrogen is now becoming important: **ammonium**. This is generated by the breakdown and recycling of organic material at and below the depth of maximum phytoplankton **chlorophyll**.
4. The ammonium, nitrate, warming and high summer light levels promote strong phytoplankton growth (high **chlorophyll**). This is most pronounced in the Firth, where the stratification keeps phytoplankton suspended in the well-lit upper water column.

Autumn:

1. By autumn, westerly winds have been replaced by mainly easterly winds in the Hauraki region. This allows high **temperature** and **salinity,** subtropical surface water to spread shoreward to cover the shelf. This stratifies the shelf water column, indicated by the thick layer of low **density** water overlying more dense water.

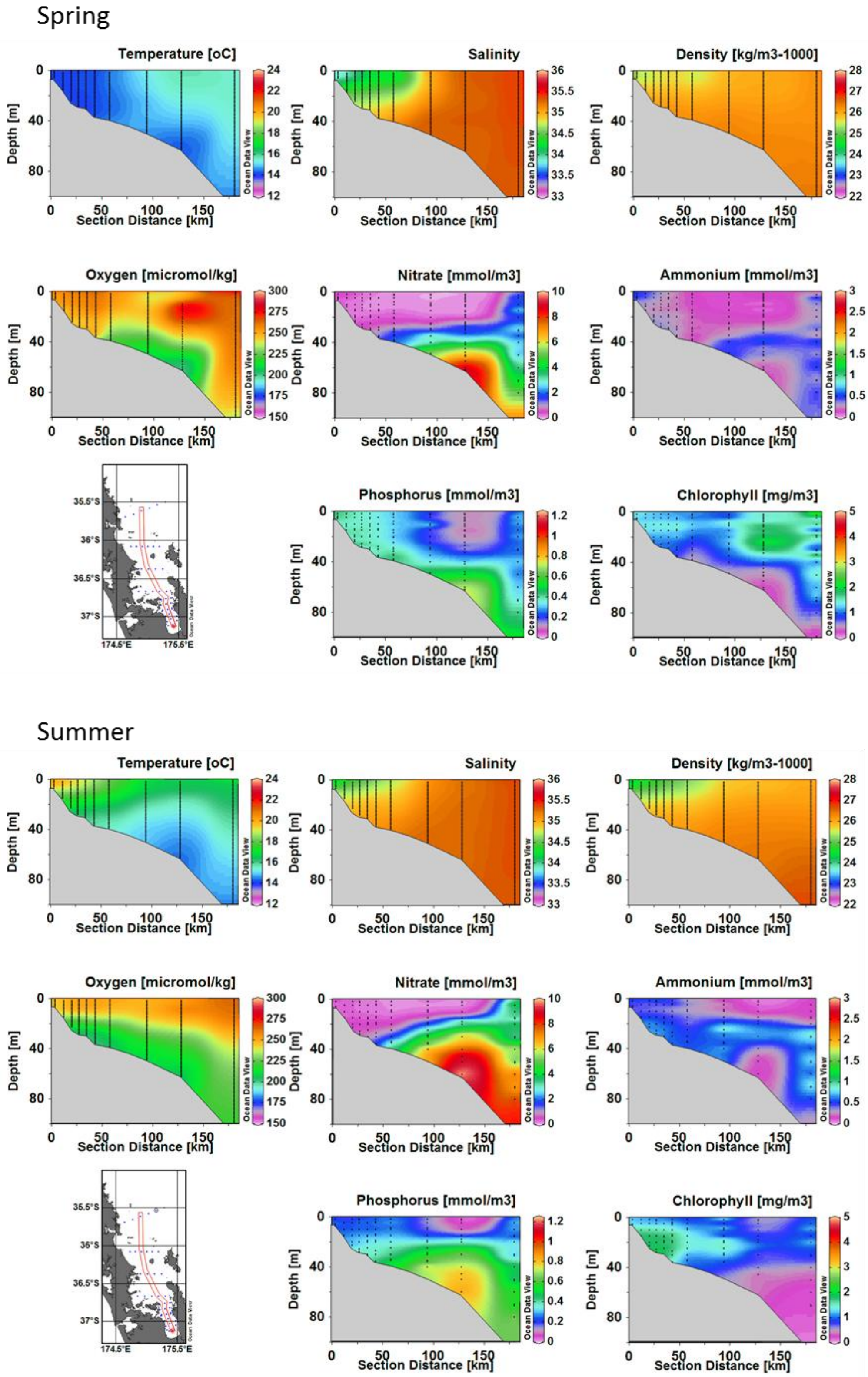
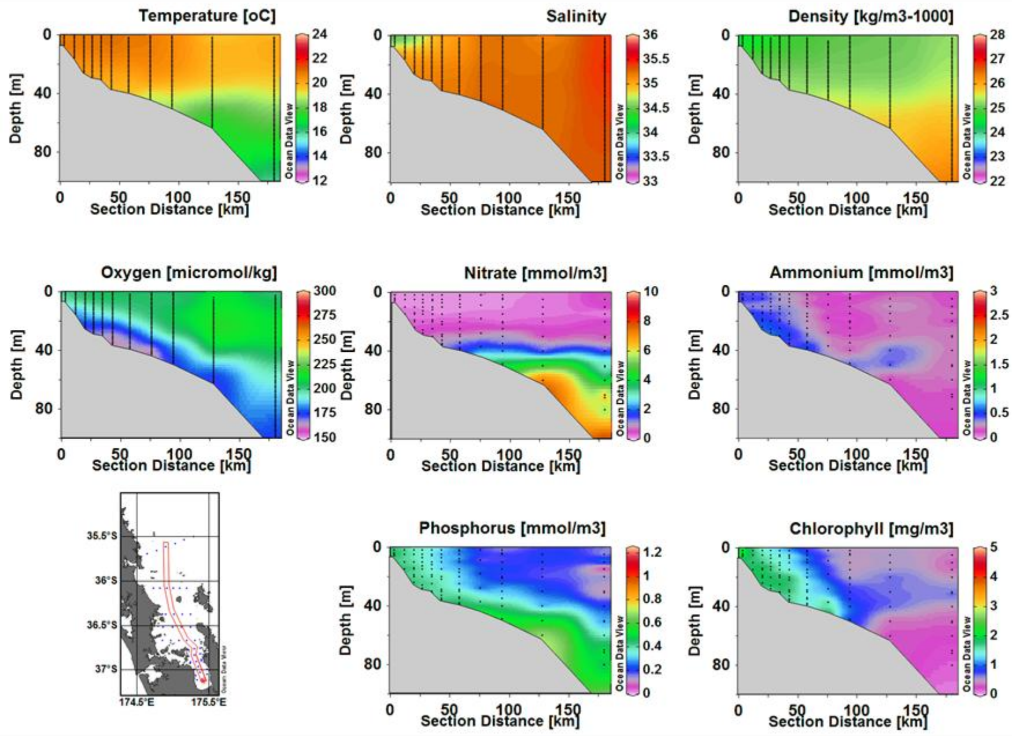


Figure 3-1: Vertical sections of water properties from inner Firth of Thames to the continental shelf edge for spring and summer. The map at lower left indicates station locations (red rectangle). Bathymetry is shown in grey, and lines and dots on the panels indicate sample depths of CTD and bottle data, respectively.

Autumn



Winter

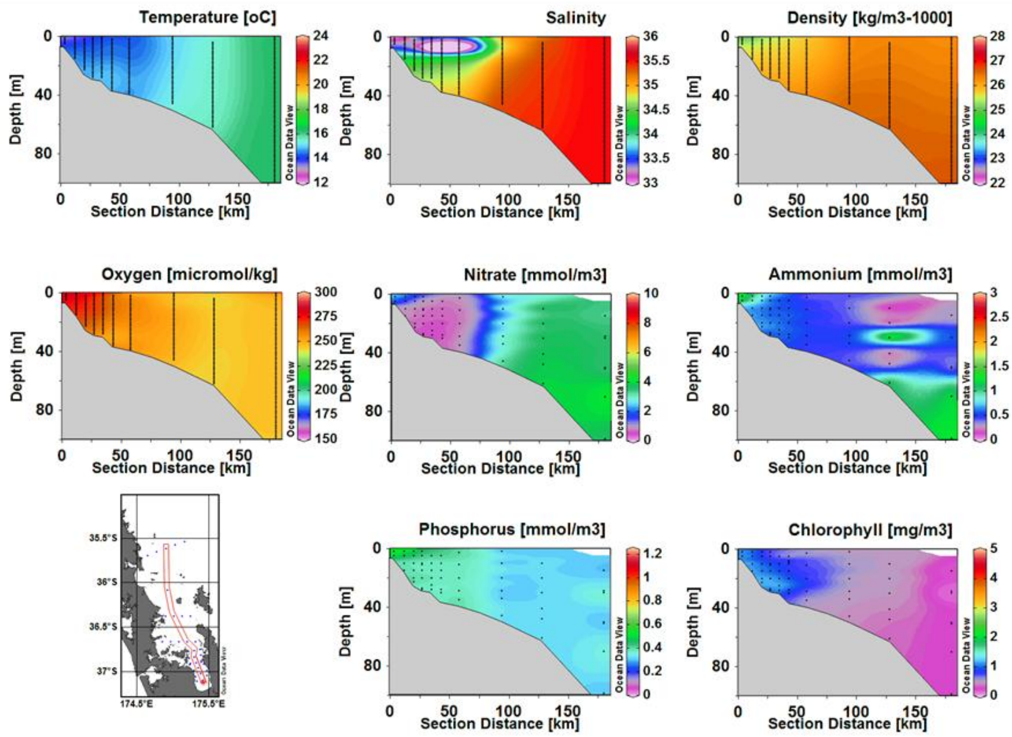


Figure 3-2: Vertical sections of water properties from inner Firth of Thames to the continental shelf edge for autumn and winter. The map at lower left indicates station locations (red rectangle). Bathymetry is shown in grey, and lines and dots on the panels indicate sample depths of CTD and bottle data, respectively.

2. The **density** stratification prevents nitrate from reaching the well-lit surface layers, causing very low phytoplankton **chlorophyll** on the shelf and in the Gulf.

3. With the nitrate supply shut off, phytoplankton production relies on **ammonium** production in the water column. This is strongest in the shallow Firth, with active phytoplankton growth (higher **chlorophyll**) throughout the water column, and also offshore in the mid-column, where ammonium is regenerated.

<u>Winter:</u>

1. In winter, **temperatures** are cold throughout the water column. Offshore, it is deeply mixed by winter storms (little **density** stratification) and, although **nitrate** is present throughout the water column, the average light levels experienced by phytoplankton are low, and phytoplankton **chlorophyll** is low.

2. In the Firth, winter river runoff lowers **salinity**, providing some **density** stratification and stability. This allows phytoplankton to adapt to ambient light conditions and assume a moderate level of biomass. Again, a consequence of this growth is near complete consumption of **nitrate**.

Two parameters shown in the figures but which are not yet discussed are **phosphorus** and **oxygen**. Like nitrogen, **phosphorus** is an essential phytoplankton nutrient. However, it is rarely the nutrient which limits production (unlike nitrogen), meaning that when nitrogen is completely depleted, there will usually still be phosphorus present. This is the reason for the considerably smaller offshore-onshore gradient of phosphorus, than of nitrate, in all seasons.

Oxygen patterns reflect both its production by phytoplankton photosynthesis, and its consumption by respiration (breakdown) of organic matter. In general, oxygen is highest in the upper water column where phytoplankton are abundant and the water is exposed to the atmosphere, whereas the lower column, which is isolated from the atmosphere and receives settling, decaying organic matter from the surface layer, has the lowest oxygen levels. An important feature appears in autumn, when a large, pronounced oxygen minimum forms near the seabed, most pronounced in the Firth of Thames. This is caused by respiration of accumulated organic matter delivered by the previous spring-summer phytoplankton growth season and by organic matter delivered by rivers.

The patterns shown by the vertical sections (Figure 3-1, Figure 3-2) are reflected in the horizontal GIS data for the two depth bands (Figure A-1,Figure A-2). In particular, prevalent upwelling of nitrate and phosphorus is seen in spring and summer, which ceases in autumn. The increasing importance of regenerated ammonium after spring is notable, especially in the Firth. Input of nitrate by river flow to Firth surface waters is seen in all seasons except autumn, when uptake by phytoplankton is most rapid and river flow least. Phytoplankton abundance, reflected by chlorophyll, is initially high in spring both offshore and inshore, but becomes increasingly isolated inshore, as the seasons progress. The Firth and western Coromandel coastline are notable for relatively high chlorophyll abundance, year-round.

4 Further reading

Bury, S.J., Zeldis, J.R., Nodder, S.D., Gall, M. (2012) Regenerated primary production dominates in a periodically upwelling shelf ecosystem, northeast New Zealand. *Continental Shelf Research*, 32(0): 1–21. http://dx.doi.org/10.1016/j.csr.2011.09.008

Chang, F.H., Zeldis, J., Gall, M., Hall, J. (2003) Seasonal and spatial variation of phytoplankton functional groups on the northeastern New Zealand continental shelf and in Hauraki Gulf. *Journal of Plankton Research*, 25: 737–758. http://plankt.oxfordjournals.org/cgi/reprint/25/7/737

Gall, M., Zeldis, J. (2011) Phytoplankton biomass and primary production responses to physico-chemical forcing across the northeastern New Zealand continental shelf. *Continental Shelf Research*, 31(17):1799–1810. http://dx.doi.org/10.1016/j.csr.2011.06.003

Giles, H., Pilditch, C.A., Nodder, S.D., Zeldis, J., Currie, K. (2007) Benthic oxygen fluxes and sediment properties on the northeastern New Zealand continental shelf. *Continental Shelf Research*, 27: 2373–2388. http://ac.els-cdn.com/S0278434307001707/1-s2.0-S0278434307001707-main.pdf?_tid=4a90a4e2-e439-11e2-bd48-00000aacb35e&acdnat=1372894729_c81bf47ef95682416be2ef0c94b3dfc3

Moore, C.M., 22 others (2013) Processes and patterns of oceanic nutrient limitation. *Nature Geosciences*, Advance online. 10.1038/ngeo1765 10.1038/NGEO1765.

Zeldis, J.R., Walters, R.A., Greig, M.J.N., Image, K. (2004) Circulation over the northeastern New Zealand continental slope, shelf and adjacent Hauraki Gulf, from spring to summer. *Continental Shelf Research*, 24(4-5): 543–561. http://authors.elsevier.com/sd/article/S0278434303002449

Zeldis, J.R. (2004) New and remineralised nutrient supply and ecosystem metabolism on the northeastern New Zealand continental shelf. *Continental Shelf Research*, 24: 563–581. http://authors.elsevier.com/sd/article/S0278434303002450

Appendix A

GIS layer plots

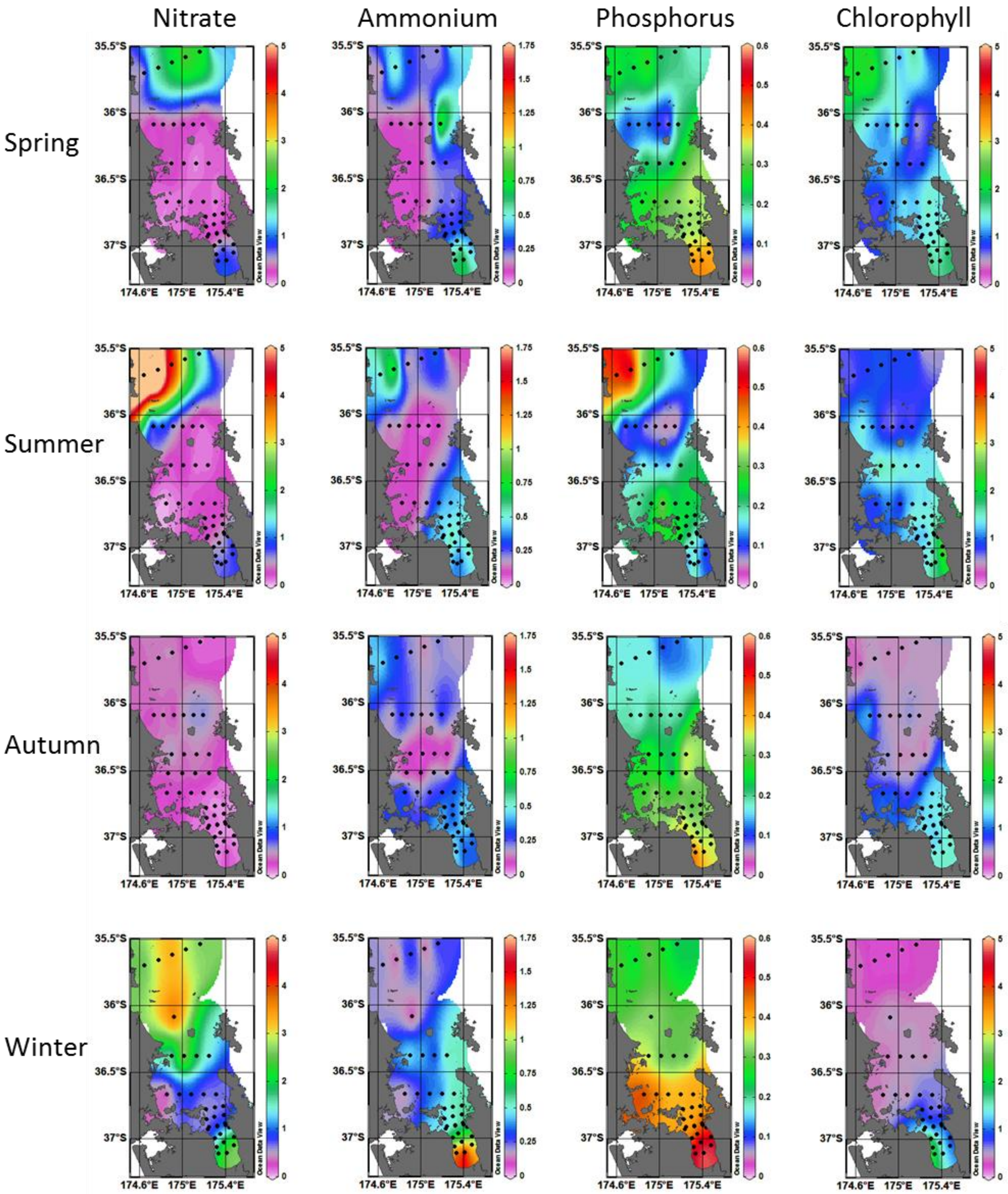


Figure A-1: Properties averaged over depths 0–15m.

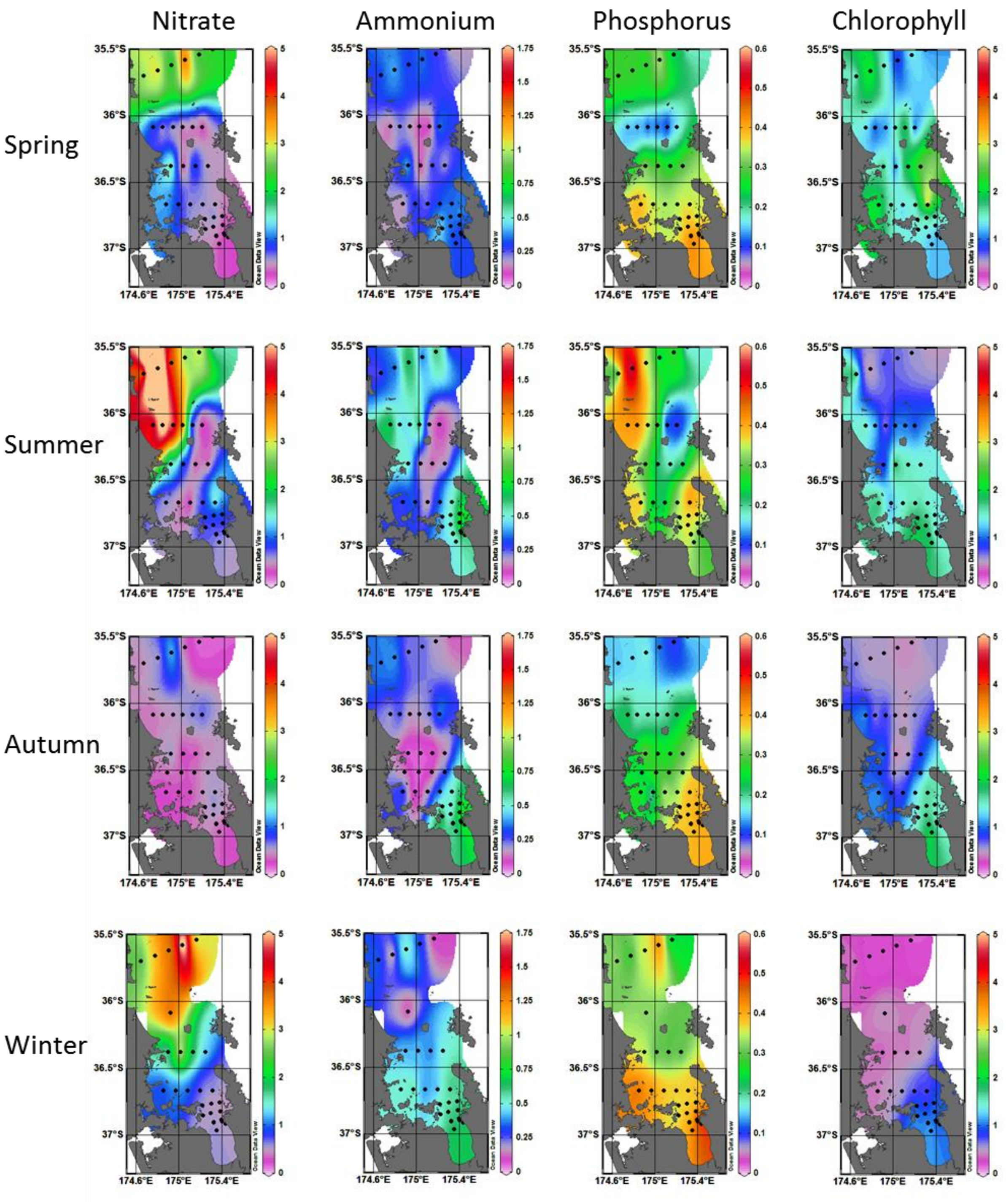


Figure A-2: Properties averaged over depths 16–50m.

Appendix B

GIS metadata

Metadata descriptions are provided for each of the 32 layers in this project. An example of the metadata for the surface ammonium layer is given below.

Ammonium 0–15m

Summary

These are interpolated values of ammonium concentration averaged over the 0–15m depth stratum of the water column averaged over all autumn surveys. Units for ammonium are micromol.

Description

Conductivity/Temperature/Depth (CTD) sampling equipment was used to acquire ammonium data in the Hauraki Gulf region over the last 17 years, in NIWA Coasts and Oceans core-funded research programmes and its predecessors (chiefly the Coasts and Oceans Outcome Based Investment (OBI). The data were averaged over the 0 to 15m stratum of the water column. Water samples (250ml) were filtered through Whatman GFF filters and frozen on board. The table below decribes the laboratory analytical method used.

Analyte	Method ID	Detection limit (mg m-3)	Method
Ammonium Nitrogen (NH4+-N)	DRP,NH4+-N,NO3--N, Simultaneous Auto-analysis	0.07 (micromol)	Astoria

Ocean Data View software (Schlitzer, R., Ocean Data View, http://odv.awi.de, 2013) was used to generate interpolated values using the weighted average gridding method. These data were used to generate raster surfaces in ESRI GRID format. These GRIDS are 1-km resolution and in New Zealand Transverse Mercator projection.

Credits

Funding agencies for this research are MBIE and its predecessors FRST and MSI. For further information contact Dr John Zeldis at j.zeldis@niwa.co.nz.