fluence of iron and nitrate
51.
ıs of the picoplanktonic alga
: zone, austral spring 1988,
. dynamics of iron in seawater.
ʼoteins, RNA, DNA and
Mar. Biol. 10 : 44-51.
. *Leptodinium viride* gen. et sp.
orophyll *a*- and *b*- containing
aeocystis pouchetii blooms in
Shelf Sci. 23:171-182.
nistry in providing a source of
; a triggering factor for red tide
sland , South Orkneys, The
-189.
ndance in western Antarctic and
180.
otenoids of the Chrysophyceae.
M.V. Nella Dan, January 1985
rine phytoplankton analysed by

Chapter IX

Summary

This research was designed to shed more light upon the factors controlling phytoplankton growth, standing stock, species composition and succession in Antarctic waters.

The spatial and seasonal distribution of various phytoplankton communities was investigated during two surveys in the Atlantic sector of the Southern Ocean. During both cruises *in situ* chlorophyll *a* levels were low, remaining far below the maximal expected level at nutrient depletion. Applying specific pigment measurements, special attention was paid to cells in the nanoplankton size range (2-20 µm), since few data were available on the quantitative contribution of this phytoplankton fraction to total biomass in Antarctic ecosystems. In the austral autumn (APSARA) the composition of the phytoplankton showed large scale similarities. Only small differences were found between the water masses under investigation. Pigment patterns revealed that green algae and dinoflagellates were of minor quantitative importance in the area, whereas Prymnesiophyceae predominated over diatoms. During the austral spring (EPOS) the composition of the phytoplankton showed much more spatial and temporal variation. During the coarse of this survey a diatom dominated phytoplankton ice edge bloom was followed by a small celled bloom, with Cryptophyceae reaching monospecific bloom conditions at the end of the cruise. This succession was found to be related with krill grazing, as found by other EPOS teams. Green algae and Prymnesiophyceae formed a large fraction of the under-ice phytoplankton stock. Diatoms were found to persist only in the Weddell Scotia Confluence during this season. The high relative importance of nanophytoplankton throughout implies that microbial pathways are of great significance in Antarctic food chain dynamics.

No "clean" study had ever been carried out before to test the hypothesis of Fe limitation of phytoplankton growth in Antarctic waters. During the second cruise (EPOS) the effect of iron on both phytoplankton development and community structure was studied.The impact of iron on phytoplankton growth was investigated by monitoring nutrient utilization, phytoplankton pigment increase and total organic carbon formation after enrichment of natural phytoplankton populations with Fe. The effects of manganese, copper and zinc were studied occasionally, showing virtually no effect. For most plankton communities Fe was found to stimulate the formation of chlorophyll *a* , total particulate carbon and the assimilation of nitrate and phosphate. Further support was provided by division rate calculations for various phytoplankton species, suggesting enhanced levels of division rate after Fe addition.

The effects of metal additions on the structure of the first trophic levels in the various water systems were studied by applying microscopy and specific pigment measurements.The addition of Fe selectively favoured the growth of diatom species. The simultaneous Fe-mediated stimulation of zooplankton (here ciliate) activity and biomass caused additional shifts in community structure in the Fe-enriched bottles towards diatom dominance, through selective ciliate grazing upon small celled phytoplankton. These observations implied first of all that Fe exerts a selective pressure on phytoplankton species *in situ* . In systems which carry elevated ambient levels of Fe, such as neritic regions and marginal ice zones, the growth of diatoms and consequently the relative uptake of nitrate versus ammonium may be favoured. It also implied that Fe-fertilization of the Southern Ocean would dramatically change the structure of the food web by generating shifts in phytoplankton communities towards diatom dominance, and probably at the same time to a proportional increase in new production and subsequent vertical particle flux.

However, there was a steady increase of chlorophyll *a* in the control bottles (no additon) as well, and the complete utilization of a major nutrient (nitrate, phosphate or silicate) within a few weeks after the start of the experiments. This proved that ambient Fe levels in the Weddell-Scotia Seas are high enough to principally support rapid build-up of phytoplankton pigment and utilization of nutrients. It also implied that the experimental conditions in the controls were more favourable for phytoplankton growth than the conditions in the field, obviously eliminating one (or more) growth suppressing factor which only exists in the field. Therefore intense grazing pressure by large herbivores such as *Euphausia superba* was suggested to play a key role in crop control, as these organisms are underrepresented after initial sampling for this type of experiment. Although to a lesser extent than in the Fe-enriched bottles, the plankton composition in the control bottles shifted towards diatom- and microzooplankton dominance as well. This finding of the simultaneous development of large diatoms and ciliates to the observed high numbers furthermore suggested the importance of top-down control of phytoplankton by zooplankton in the field. It was concluded that although Fe plays a role as a rate limiting factor, grazing seems an important feature in keeping nutrient concentrations high and phytoplankton standing stocks low, at least in the area investigated during EPOS. Future research should focus on the role of Fe in more remote areas of the Antarctic. Here the presumed low(er) ambient Fe levels would have a more pronounced impact on phytoplankton growth, species composition and new production.

One study focussed on features of growth performance and photoadaptation kinetics under changing light conditions in three Antarctic nanoflagellates. This study, based on semi-continuous culture experiments, demonstrated first of all that these algae were capable of photoadaptation to low light fluxes. Division rates at saturating light intensities at the experimental temperature fell within ranges given for polar diatoms, as presented in the literature. The reported long times required for the establishment of new "balanced" division rates and constant fluorescence levels after a light transition, implied poor photoadaptational behaviour in the tested organisms. However, during the period of unbalanced growth internal buffers seemed to support high division rates. Therefore overall growth performance of these algae during transient state periods was not negatively affected by long periods of unbalanced growth and poor kinetic behaviour with respect to changes in cell characteristics. Polar algae do not seem capable of adaptation to large down-shift steps in the light intensity, which was confirmed in this study. Strong light stress was observed after a shift down from 400 to 25 $\mu E.m^{-2}.s^{-1}$: for at least one month following the shift growth was strongly retarded and cellular chlorophyll content and cell size kept their "sun" adapted characteristics. This implied that surface phytoplankton communities which are transported from the surface to deeper waters by a wind-mixed layer deepening event, or which are advected beneath sea-ice, may have problems to adapt to low *in situ* light conditions. Features of susceptibility to strong gradients in irradiance may have an impact on species composition, competition and succession in the dynamic Antarctic light climate.

Conclusions. It is concluded from this thesis that phytoplankton production and species composition in Antarctic waters is governed by a complex of inter-dependent factors. Phytoplankton growth may be restricted by temperature, iron availability or poor light conditions, whereby a balance between phytoplankton growth and loss factors (like grazing) is established. Therefore elimination of one rate limiting factor under certain circumstances would allow phytoplankton growth to escape grazing control, leading to occasional increased levels of phytoplankton stocks or blooms. On the other hand, even though grazing is the proximate control, the supply of iron might ultimately regulate productivity by principally influencing species composition and food web structure. Furthermore the relative importance of rate and stock limiting factors will differ for the various ecosystems encountered in the Southern Ocean. In open remote parts of the Southern Ocean rate limiting factors like iron levels and light conditions will have a strong impact on phytoplankton growth and species composition. This is not likely in neritic regions and marginal ice zones. Here strong grazing pressure likely prevents the phytoplankton from exploiting the available nutrients in surface waters. It is of importance for future research in high-nutrient, low chlorophyll regions of the world's oceans, to consider the interaction of rate- and stock limiting factors, rather than to focus on the role of one single limiting factor.