ICES 1999 Annual Science Conference, CM 1999/N: 05
On the Management and Mitigation of harmful algae

The life with harmful algae in Norway – management

Einar Dahl and Karl Tangen

Abstract

Harmful phytoplankton is a part of the natural, marine flora. The need for management and mitigation of their occurrence and effects has raised with the increased use and utilization of the coastal waters. Besides fisheries, fish farming and harvesting/cultivation of bivalves are activities in Norway, which have experienced problems, including economic losses, due to harmful algae. Management tools for tackling such problems and minimize losses are proper site selection of aquaculture installations, regular monitoring of algae and fast spreading of actual information to the industry and public. In some cases the information has included a kind of risk assessment and advice on how to adapt to the situation. When harmful blooms appear we usually put efforts on mapping of the distribution of the bloom, including its propagation and transport with surface currents. For new species blooming we have in addition looked for potential unknown toxins involved with special emphasis on control of organisms exposed to the bloom.

Key words: harmful algae, management, Norway

Einar Dahl, Institute of Marine Research, Flødevigen Marine Biological Station, N-4817 His, Norway [tel: +47 37059000, fax: +47 37059001, e-mail:einar.dahl@imr.no]. Karl Tangen, OCEANOR, Pirsenteret, N-7005 Trondheim, Norway [tel: +47 73545200, fax: +47 73545201, e-mail: karl.tangen@oceanor.no]

Introduction

In this century, up to the seventies, single episodes of mussel toxicity and mortality of wild biota were recorded along the Norwegian coast; however, without leading to a managing policy. Through the seventies several fish farms were established along the coast. In 1981 a large bloom of *Gyrodinium aureolum* caused significant mortality among farmed salmon and economical losses to the fish farmers (see Dahl and Tangen, 1993). The bloom caused much public attention. Both the fish farming industry and the authorities learned that harmful algae could be a threat to activities in our coastal waters. New blooms of *Gyrodinium* followed, and during the eighties also other phytoplankton species bloomed and caused problems; *Dinophysis* spp. in 1984 (Dahl and Yndestad, 1985), *Chrysochromulina polylepis* in 1988 (Dahl *et al.*, 1989), recurrent blooms of *Prymnesium* since 1989 (Johnsen and Lein, 1989), *Chrysochromulina leadbeateri* in 1991 (Edvardsen, 1993) and *Chattonella* in 1998 (Horstmann *et al.*, 1998). Since the end of the eighties, possible causes to harmful blooms of phytoplankton, as well as strategies on tackling the threat and the problems from harmful algae, have been on the agenda. Management tools for tackling such problems and minimize losses can be grouped in:1) proper site selection of aquaculture installations; 2) regular monitoring of algae; 3) fast spreading of actual information from the monitoring to the industry and public; 4) attempts on risk assessment and advice on how to adapt to a possible bloom situation. When harmful blooms have occurred we usually have made efforts on tracing and mapping the bloom, including its propagation and transport with surface currents. For new species blooming we have in addition looked for potential unknown toxins involved with special emphasis on control of organisms exposed to the bloom.

Site selection

From nearly twenty years of monitoring we know that most of the Norwegian coast may occasionally be hit by harmful algae threatening fish in cages, but the bloom frequency has been highest along the southern coast of Norway and lowest in northern Norway. In addition some inshore waters along the coast have enhanced risk for *in situ* growth of harmful algae. The risk for occurrence of harmful blooms has; however, not been the main criterion for selection of sites for fish farms, but a contributing argument for permanently moving farms from east to west along the Skagerrak coast, and for reducing the number of farms in a fjord area at the west coast recurrently hit by local blooms of *Prymnesium* (Johnsen and Lein, 1989). As harmful concentrations of algae are most common in the upper 0-5m many fish farmers have got deeper cages to reduce losses from harmful blooms. This may locally have lead to relocation of cages to deeper areas. Today the depth below cages are generally larger than before.

So far the mussel production in Norway is small, but from monitoring of mussel toxicity due to algae we already know that some areas are more likely to have toxic mussels than other areas. Toxins causing paralytic shellfish poisoning (PSP) and diarrhetic shellfish poisoning (DSP) are common in Norway. In addition yessotoxin (YTX) (Aune *et al.*, 1991) and some unknown toxins (Aune *et al.*, 1996) have been recorded, while domoic acid causing amnesic shellfish poisoning (ASP) has not been found. Paralytic toxins may occur all along the coast with some "hot spots" in mid-Norway. Diarrheagenic toxins occur most frequently along the coast of Skagerrak and in the inner parts of the large fjords at the west-coast of Norway, and seem more rare in northern Norway. This knowledge seems to be used, to some extent, by people now establishing new mussels plants along the coast.

Monitoring

The growing of the fish farming industry along our coast since the seventies and the increasing interest for harvesting of mussels have called for a monitoring and ideally an early warning of possible harmful blooms of phytoplankton. So, from 1981 a rather regular monitoring of selected harmful algae has been operative (Dahl 1989). Simultaneously a monitoring of paralytic shellfish toxins was established (Yndestad and Underdal, 1985). After the beginning in 1981 the monitoring and forecasting/information activities have, however, been modified and reorganized several times. For some years in the eighties the fish farmers organized a network, "MARINET", for rapid exchange of information including possible harmful blooms, but the service was considered too

expensive and complicated by many fish farmers, as computers were not so widespread at that time. Then, in the early nineties, the Norwegian Ministry of Environment funded a program for ocean monitoring and forecasting which included algae (acronym HOV), but this program was evaluated and stopped after about three years because it was not considered cost/effective enough.
Today regular monitoring is done at 27 stations along the coast (Fig. 1) with a weekly frequency in the period, March-October. It is a joint effort by more than seven institutions, partly financed by the Norwegian State Food Control Authority (SNT). In addition the participating institutions contribute with data and information they may get from other, algae related, activities. OCEANOR, for instance, share information from work done for insurance companies, fish farmers and mussel plants. In our opinion today algal monitoring in Norway is cost/effective, but too individually dependent, There are some pressure from the aquaculture industry on the Ministry of Fisheries to put more governmental resources into algal monitoring as a future support to the industry. The main objective of the monitoring program is to provide an early warning of algal blooms that may be a threat to caged fish or cause toxicity in shellfish. The harmful species included in the program related to shellfish toxicity are; *Alexandrium* (PSP), *Dinophysis* (DSP) and *Pseudo-nitzschia* (ASP), while *Gyrodinium, Chrysochromulina, Prymnesium,* diatoms and Raphidophyceae are looked for because they have caused fish mortality in Norway. New harmful species in our waters, sometimes unexpected as harmful to the scientific community (for instance *Chrysochromulina polylepis*) was not warned against before first appearance, but recurrent appearance of potential harmful algae have usually been caught up by the monitoring. For some species and areas we have established "normal occurrence" as a result of about 10 years of regular monitoring (Dahl and Johannessen, 1998).

Information on the algae-situation

The information on the algae-situation along our coast is now given (in Norwegian) via Internet as a weekly updated web-side with address, http://www.efan.no/alger/alg.htm. The information consists of a map with symbols indicating the algae-situation along the coast and a short text for closer description, and there are links to useful additional information. If acute situations should occur more frequent updating is possible as well as direct contact to management authorities and aquaculture industry in threatened areas.

Early warning, risk assessment and advice

During years we have done a few attempts to carefully point to a risk for large harmful blooms based on data of unusual environmental or meteorological conditions. Such could be high levels of nutrients (nitrogen), unusual nutrient ratios or heavy precipitation (Dahl *et al.*, 1987). Retrospective we have in most cases failed. It is, to our experience, associated with great uncertainties to predict a bloom of a harmful alga before the alga in question is present in typical pre-bloom concentrations over larger areas. From that stage the bloom may cease or it may grow to harmful concentrations in about one week or more. One week is considered useful for threatened aquaculture installations to prepare mitigation activities in case a bloom should occur.

Advice on the risk for toxicity of mussels are available at the address, http://www.snt.no/nytt/blaskjell/. The latter information is also available on a "mussel-phone" or on text-TV (Norwegian Broadcasting). The basis for the advice may be results from monitoring of toxicity in mussels, but we mostly use data on occurrence of potential toxic phytoplankton as a tool for advice to public and mussel producers. From own experience and literature (Andersen, 1996) we have established levels of warning or recommended concentration limits of selected toxic algae not to be exceeded. If the levels are exceeded the public are recommended not to pick and consume wild mussels and mussel producers may experience that their stock of mussels accumulate algal toxins. Examples of such levels are: *Alexandrium* spp. constitute about 1% or more of the net-plankton (20 micrometer mesh size net), and *Dinophysis acuminata, D. acuta* and *D. norvegica* exceed 900, 900 and 1200 cells/L respectively. One problem using only occurrence of algae as a basis for advice is the high variability of toxin content per cell. Application of the precautionary principle, supposing potential toxic algae are always toxic, has lead to several false alarms concerning toxicity of the wild mussels. The good thing is that to our knowledge no one who has followed the official advice has so far become intoxicated from consumption of wild mussels. A more serious problem is that in a few cases we have recorded toxicity in mussels according the mouse bioassay without any obvious indications from the algae assemblage.

Mapping of blooms

When harmful blooms have occurred in Norwegian waters we usually have put efforts on tracing and mapping the bloom, including its propagation and transport with surface currents. This has most often involved field observations with research vessels, and then additional environmental data to describe the bloom conditions have also been collected. From such efforts it is more likely to get sufficient data for a better understanding of a specific bloom. In some cases also airplanes and satellite images have been used for mapping of blooms (Horstmann *et al.*, 1998). Propagation and transport of blooms have in some cases been recorded by continuous measurements of water movements by anchored buoys (Johnsen *et al.* 1997) or predicted using models.

Control of toxins in organisms

A shellfish producer has to check the toxin status in mussels before harvesting, as a part of the obligate documentation before marketing. In addition it has been common practice to look for potential toxins involved when blooms of harmful algae occur, with special emphasis on possible toxins in fish and other organisms exposed to the algae. Besides the more basic interests of such practice, to see if, or which, toxins are involved and in which organisms and organs, it is crucial information to the public and the market during larger blooms of harmful algae. We have a positive experience from an open communication with the public on the state of knowledge during harmful blooms, and it seems to function precautionary on irrational reactions from the market.

Acknowledgements

All colleagues participating in the monitoring are acknowledged for fruitful co-operation. The monitoring is partly funded by the Norwegian State Food Control Authority (SNT).

References

Andersen, P. 1996. Design and implementation of some harmful algal monitoring Systems. IOC technical series 44: 1-110 + Annex of 10p.

Aune, T., Yasumoto, T. and Engeland, E. 1991. Light and scanning electron microscopic studies on effects of marine algal toxins toward freshly prepared hepatocytes. J. Toxicol. Environ. Health 34: 1-9.

Aune, T., Dahl, E. and Tangen, K. 1995. Algal monitoring, a useful tool in early warning of shellfish toxicity?. Pp. 765-770; in: Lassus, P., Arzul, G., Erard, E., Gentien, P. and Marcaillou, C. (eds), Harmful Marine Algal Blooms, Technique & Documentation, Lavoisier, Paris.

Aune, T., Strand, Ø., Aase, B, Weidemann, J., Dahl, E. and Hovgaard, P. 1996. The Sognefjord in Norway, a possible location for mussel farming? Pp.73-75 in: Harmful and Toxic Algal Blooms. Yasumoto, T., Oshima, Y. and Fukuyo, Y. (Eds), Intergovernmental Oceanographic Commission of UNESCO, Paris.

Dahl, E. 1989. Monitoring of toxic phytoplankton causing fish mortality and mussel toxicity in Norwegian waters. Pp. 21-28. in: Aquaculture - A biotechnology in progress. De Pauw, N., Jaspers, E., Ackefors, H. and Wilkins, N. (Eds),. European Aquaculture Society, Bredene, Belgium.

Dahl, E. and Yndestad, M. 1985. Diarrhetic shellfish poisoning (DSP) in Norway in the autumn 1984 related to the occurrence of *Dinophysis* spp., pp.495-500. in: Toxic Dinoflagellates. Anderson, D.M., White, A.W. & Baden, D.G. (Eds), Elsevier, New York.

Dahl, E. and Tangen, K. 1993. 25 years experience with *Gyrodinium aureolum* in Norwegian waters. pp.15-21 in: Smayda, T.J. & Shimizu, Y. (edit.) *Toxic Phytoplankton Blooms in the Sea. Elsevier, New York.*

Dahl, E. and Johannessen, T. 1998. Temporal and spatial variability of phytoplankton and chlorophyll *a*:: lessons from the south coast of Norway and the Skagerrak. ICES Journal of Marine Science, 55: 680-687.

Dahl, E., Danielssen, D.S., Semb, A. & Tangen, K. 1987. Precipitation and run-off as a fertilizer to a *Gyrodinium aureolum* Hulburt bloom. *Rapp. P.-v. Réun. Cons. int. Explor. Mer 187:* 66-73.

Edvardsen, B. 1993. Toxicity of *Chrysochromulina* species (Prymnesiophyceae) to brine shrimp, *Artemia salina*, pp.681-686. in: Toxic Blooms in the Sea. Smayda, T.J. and Shimizu, Y. (Eds), Elsevier, Amsterdam.

Horstmann, U., Lu, D., Göbel, J., Davidof, A., Dahl, E. and Kaas, H. 1998. Tracing a toxic algal bloom of *Chattonella* around the southern Norway and West Juetland, using MOS and SeaWiFS satellite data. 2nd International Workshop on MOS-IRS and Ocean Colour, Wissenschaft und Technik Verl., Berlin, 1998, pp. 303-311.

Johnsen, G. Volent, Z., Tangen, K. and Sakshaug, E. 1997. Time series of harmful and benign phytoplankton blooms in Northwest European waters using the Seawatch buoy system. Pp. 113-141 in: Monitoring algal blooms: New techniques for detecting large-scale environmental change. Kahru, M.F. and Brown, C.W. (Eds), Landes Bioscience, Austin, Texas.

Johnsen, T.M. and Lein, T.E. 1989. *Prymnesium parvum* Carter (Prymnesiophyceae) in association with macroalgae in Ryfylke, southwestern Norway. Sarsia 74: 277-281.

Stations 1999

1. Borg, Kvernskjær
2. Mossedistriktet, Gullholmen
3. Asker og Bærum, Konglungen
4. Tønsberg, Vallø
5. Drangedal/Kragerø, Langåresund
6. Aust-Agder, Flødevigen
7. Vest-Agder, Dalskilen
8. Dalane, Nordasundet
9. Midt-Rogaland, Lundsvågen
10. Haugaland, Skjoldastraumen
11. Ytre Sunnhordland, Sydnes i Hardangerfjorden
12. Bergen og omland, Hjellefjorden
13. Nordhordaland/Gulen, Kvalvågneset (Lurefjorden)
14. Sogndal, Menes i Balestrand
15. Nordfjord, Almenning
16. Romsdal, Cap Clara
17. Ytre Nordmøre, Ekkilsøy
18. Frøya og Hitra, Frøya
19. Trondheim, Pir 1
20. Rissa, Kvithyll
21. Namdal, Allebotn
22. Brønnøysund, Vistenfjorden
23. Salten, Mørkved
24. Harstad, Vik i Kvæfjord
25. Tromsø, Sandnessundet
26. Alta, Kåfjord
27. Øst-Finnmark, Vadsø

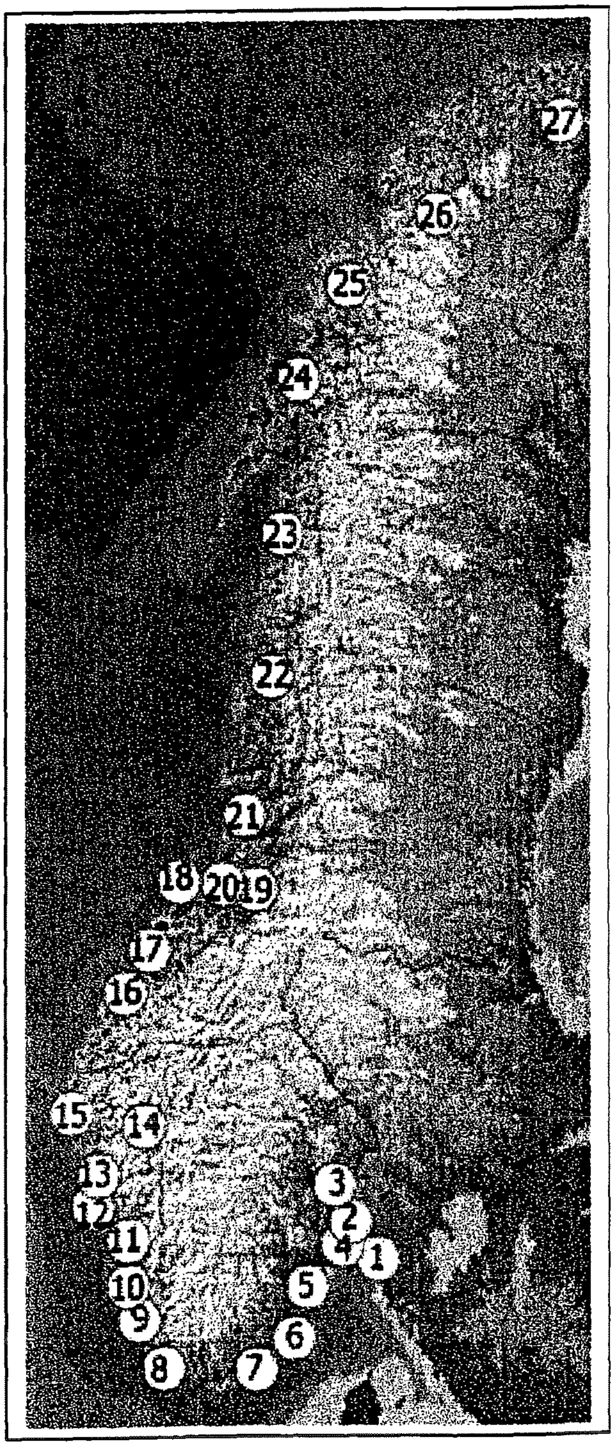

Fig.1 Monitoring stations for harmful algae in Norway 1999, funded by SNT.