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Harmful algal monitoring programme and action plan design

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22.1 Introduction

The reasons for establishing HAB monitoring are manifold and may include protecting public health, fisheries resources, ecosystem structure and function, and coastal aesthetics (Table 22.1). The appropriate design of a monitoring programme for harmful algae requires an understanding of at least some of the many factors that regulate the dynamics of HABs and the manner in which they cause harm but, by itself, that knowledge does not provide protection of resources. In order to protect resources, application of management and mitigation strategies of many different types is needed. An effective monitoring/management system for HABs therefore must have a variety of elements. As an example, impact prevention requires that the monitoring programme be designed to detect cells or toxins sufficiently early to take appropriate management actions. Those management actions should be clearly defined for each of the many different types of HAB impacts.

Table 22.1 Some typical objectives and goals of HAB and environmental water quality monitoring programmes (modified from Andersen 1996)

Monitoring Goals
HAB monitoring: • prevent algal toxins from reaching human consumers of shellfish; • protect humans from algal toxins delivered via sea spray or direct contact (e.g., *Karenia brevis* and *Pfiesteria piscicida* toxins); • prevent algal toxins from reaching consumers of drinking water (from surface waters or desalination plants); • minimize damage to living resources such as shellfish and fish; • minimize economic loss to fishermen, aquaculturists, tourist industry, etc.
General water quality monitoring: • establish basic knowledge about form and function of the ecosystem investigated and the extent to which it is influenced by anthropogenic factors; • establish detailed knowledge about selected ecosystem processes to make it possible to understand and predict ecosystem response to eutrophication or exceptional physical and biological events; • establish patterns and trends for algal populations.

Most of the existing HAB monitoring programmes (87%) are designed by government agencies to fulfil a combination of national, regional and international obligations and objectives (Andersen, 1996). They typically include regulations of shellfisheries in relation to occurrence of algal toxins in shellfish flesh and the occurrence of the algae known to potentially produce the accumulated toxins. Other HAB monitoring programmes may be designed and implemented by private companies to protect aquaculture (6%), or as cooperative monitoring programmes between government agencies and private companies (9%) (IOC, 2001). Resource-specific HAB monitoring programmes exist in many countries/regions, and most HAB monitoring programmes also aim to provide public health safety. Examples of typical objectives of these programmes are given in Table 22.1. Table 22.2 provides an overview of which resources various countries are protecting through establishment of HAB monitoring programmes.

22.2. The design elements of HAB monitoring programmes

A HAB monitoring programme is composed of a number of design elements. These must reflect: (i) the objectives of the monitoring programme; (ii) the facilities and resources available; (iii) the specific demands of the end-users of the data; and (iv) the legislation and regulations imposed by the responsible national or regional authorities.

The design of a given HAB monitoring programme must obviously be adapted to local conditions and circumstances and, wherever possible, be interfaced with other monitoring efforts, such as those for general environmental monitoring. It should also take into account the physical and biological regime, available technology, expertise and competence of the staff to carry out the monitoring and management procedure, as well as the local tradition for administration (Andersen, 1996).

However, there are a number of basic or generic elements of a HAB monitoring programme (Figure 22.1):

- Sampling of plankton, shellfish, fish and water
- Analysis of the samples (identification of harmful algae, quantification of harmful algae, measuring toxicity in water, shellfish or fish)
- Environmental observations such as discoloration of the water, fish kills and other animal behaviour
- Evaluation of results
- Dissemination of information and implementation of regulatory action
- Action plans/Mitigation measures.

22.2.1 Acquisition of data

The acquisition of data involves observation, sampling, examination of samples and analysis of raw data. The parameters to be monitored depend on the resource being protected by the monitoring and the associated action plan. Table 22.3 gives an overview of the linkage between the resource to be protected from HAB effects, the potential HAB impact on the relevant resources and the basic parameters to be monitored in order to manage the different resources.

TABLE 22.2 Overview of which resources various countries are protecting through establishment of HAB monitoring programmes. (IOC, 2001)

Country	Fish culture	Fish wild stocks	Mollusc culture	Molluscs wild stocks	Crustacean culture	Natural ecosystems	Public safety	Quality control of products	Recreational/ Tourist aspects
Australia–Tasmania	X		X	X			X	X	
Brazil						X			X
Bulgaria		X		X		X			X
Cameroon	X	X				X	X	X	X
Canada-Atlantic	X	X				X	X		
Chile			X	X			X		
China, P.R.	X	X	X	X	X	X	X	X	X
Denmark	X		X	X			X	X	
France	X	X	X	X		X	X		X
Germany			X			X	X		X
Hong Kong, SAR	X		X				X		
Ireland	X		X				X	X	
Israel									
Italy	X	X	X	X		X	X	X	X
Japan	X		X	X			X	X	X
Korea, South	X	X	X	X		X	X	X	X
Kuwait	X	X				X	X		X

.../...

TABLE 22.2 *(Suite)*

Country	Fish culture	Fish wild stocks	Mollusc culture	Molluscs wild stocks	Crustacean culture	Natural ecosystems	Public safety	Quality control of products	Recreational/ Tourist aspects
Malaysia			X		X	X	X		X
Netherlands			X	X	X	X	X		X
New Zealand	X	X	X	X			X	X	X
Norway	X	X	X	X			X	X	
Philippines–Bataan		X		X			X	X	
Portugal	X	X	X	X	X	X	X	X	X
Qatar						X	X		
Romania		X		X					X
Seychelles		X					X		
Slovenia							X		
Spain						X	X		X
Spain-Monteverdi	X		X	X		X	X	X	X
Sweden–Baltic							X		
Thailand	X		X	X			X		X
Tunisia			X	X			X		
Turkey			X	X			X	X	
UK–England & Wales			X	X			X		

.../...

TABLE 22.2 *(Suite)*

Country	Fish culture	Fish wild stocks	Mollusc culture	Molluscs wild stocks	Crustacean culture	Natural ecosystems	Public safety	Quality control of products	Recreational/ Tourist aspects
Uruguay		X	X	X		X	X	X	X
USA-Maine			X	-- X			X	X	X
USA-Delaware		X				X	X		X
USA-New Jersey						X	X		X
USA-New York State	X	X	X			X	X		X
USA-New York-Suffolk		X		X		X			X
USA-North Carolina						X	X		X
USA-Texas	X	X				X	X		X
USA-Washington							X		
Venezuela		X	X	X	X	X	X	X	X
Vietnam	X		X	X	X		X	X	

It is important that all routines for sampling, sample analysis, data analysis a storage be clearly defined and that the staff responsible for each step in the proc have access to detailed descriptions of the relevant methodologies. It must be cl which institution/person is responsible for compilation/synthesis of the monitori results and how the results of the synthesis are to be presented to the users of t programme. Pre-printed forms should be available to be filled in with the monitori data as well as additional information on the sampling, such as location/positic

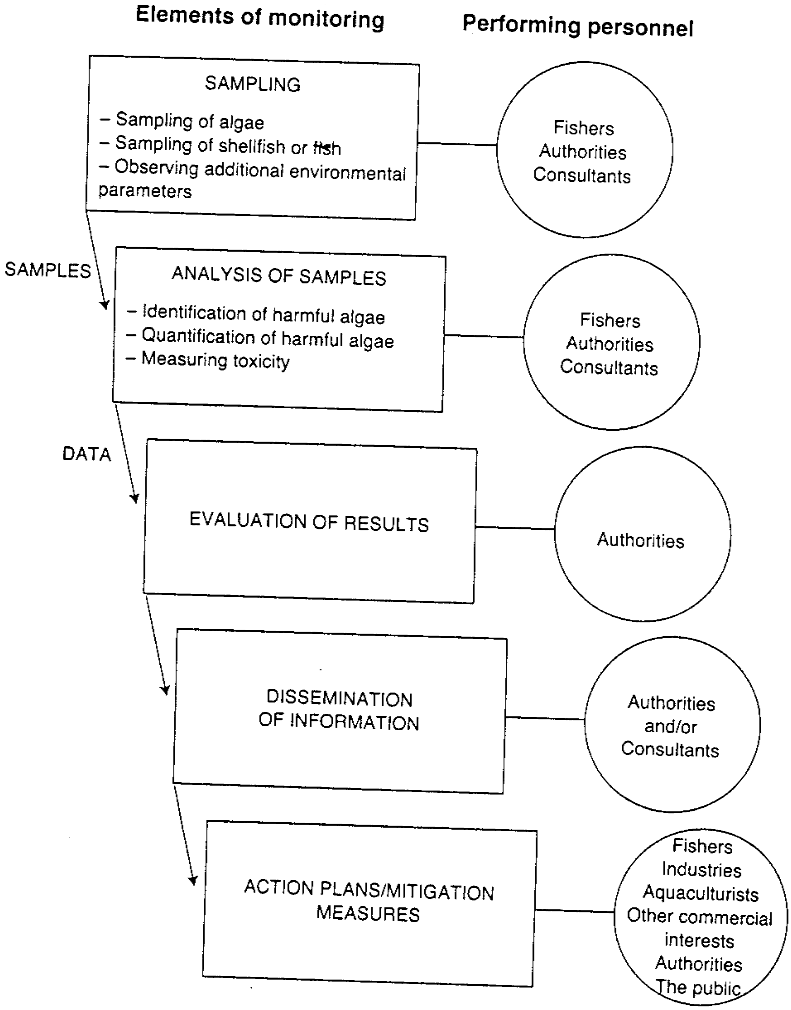

Figure 22.1
Theoretical design elements of a HAB monitoring programme indicating how information should be passed from one element to the next, and who is carrying out each process.

station name/number, and identification code for the staff responsible for the sampling. 'Raw' data from the monitoring programme should be kept in files, paper or electronic form for later reference and investigation. It is recommended that the data be stored in a computer database to facilitate data handling, quality assurance and

TABLE 22.3 An overview of the linkage between the resource to be protected from HAB effects, the potential HAB impact on the relevant resources and the basic parameters to be monitored in order to manage those resources

'Resource' to protect	HAB impact on resource	Monitoring parameters
A. Direct impact on humans		
Shellfish for human consumption	Toxicity due to accumulation of algal toxins in shellfish flesh	Algal toxins in shellfish flesh and occurrence of harmful algae
Fish for human consumption	Toxicity due to accumulation of algal toxins in fish meat	Algal toxins in fish meat and occurrence of harmful algae
Drinking water	Toxicity due to occurrence of algal toxins in surface water and desalination plants	Algal toxins in drinking water and occurrence of harmful algae in the source water
Recreational use of coastal waters/lakes/rivers	Intoxication due to exposure to algal toxins in water/aerosols/air Loss of aesthetic value due to discoloration of water Odour and smell due to degradation of algae	Harmful algae, algal toxins
B. Economic impact		
Wild fish stocks	Fish kills, stress	Harmful algae, fish behaviour, occurrence of dead fish
Aquaculture	Fish kills, stress, inhibit growth	Harmful algae, fish behaviour, occurrence of dead fish
C. Environmental impact		
Biota/ecosystems	Change of biological community structure due to kill off and/or inhibition of growth as a result of intoxication and/or oxygen deficiency	Harmful algae, species-specific behaviour, die-offs, lowered recruitment, etc.
D. Conservation impact		
Endangered/protected species	Kills/stress/inhibition of growth and reproduction	Harmful algae, behaviour of species of interest, die offs, inhibition of reproduction

analysis. Before data or results are released to the monitoring or management system, they should be properly checked by at least one person who did not perform the analysis. Once the results of the different analyses are available, it is important that well-defined routes for communication of the results be available in an official manual which defines:

- types of samples to be collected and sampling methodology;
- types of analyses to be performed;
- institution/individual responsible for collecting the samples;
- institution/individual responsible for analyses of the samples;
- how the data are archived and analyzed;
- quality assurance procedure;
- documentation (forms to be used);
- data analysis;
- data archiving;
- data presentation and evaluation.

An example of a well-designed HAB monitoring manual is the New Zealand National Marine Biotoxin Management Plan (Marine Biotoxin Management Board, 1996). The manual is set up so that pages are easily removed and replaced with updated versions. Material in the manual includes details of the administration of the national plan, methodological details, harvesting closure and re-opening procedures, methods for investigating toxic shellfish poisoning cases, product control, as well as a range of appendices with definitions, forms and other details. The New Zealand Monitoring Programme is described in detail as a specific case study in Chapter 23.

It is often the case that the personal experience of individuals who have been directly involved in the analysis of HAB data over many years allows those individuals to make forecasts or predictions of HAB incidents or transport. These individuals are extremely valuable to monitoring programmes, and every effort should be made to keep them involved in programme activities. Though non-quantitative, this type of empirical analysis is often quite accurate for predictive purposes.

Complementary marine environmental data are equally important in the analysis of already acquired HAB data as they are a basis for an early warning. Provided that the environmental data are available close to real-time, they may allow or support adjustments in HAB monitoring mode and associated action plans (for details see Anderson *et al.*, 2001). Monitoring marine environmental conditions in relation to HABs can be carried out at different levels of temporal and geographical, as well as vertical and horizontal, resolution depending upon which kind of harmful algal bloom is to be monitored (see Chapter 21). Furthermore, depending upon the goal of the monitoring, it can include a range of biological, chemical and physical parameters (Table 22.4). The list is long and is meant only as a general guideline. Specific programmes may find that only a subset of these parameters is relevant to their goal.

22.2.2 Operational HAB monitoring – action plans and mitigation measures

HAB monitoring programmes must be dynamic, that is, they must be able to operate in different modes as a response/adaptation to changes in present HAB situations. Such responses could be increasing the frequency of sampling and/or the geographical coverage of the monitoring. Furthermore, the monitoring of toxicity in shellfish and fish can be intensified in case a HAB is observed.

TABLE 22.4 Examples of potential environmental parameters to be included in HAB monitoring programmes

Physical	Chemical	Biological
Temperature (vertical profile or remote sensing data) Current speed and direction (vertical profile) Wind speed and direction Light attenuation/turbidity	Salinity (vertical profile) Oxygen content (vertical profile) Chlorophyll (vertical profile or remote sensing data) Nutrients: – Nitrogen – Phosphorous – Silicate	Phytoplankton – Harmful species – All species Meso-zooplankton Proto-zooplankton Pelagic bacteria Fish Benthos Birds

The following monitoring modes are suggested:

- Normal/routine mode (to operate in non-HAB situations);
- Watch mode (to operate when a HAB is observed but in rather low concentrations or when low levels of algal toxins are detected in shellfish and/or fish);
- Alert mode (to operate when a HAB is observed in critical concentrations, when algal toxins are observed in concentrations close to or exceeding regulatory limits or where HAB effects on fish are observed).

The change of a HAB monitoring programme from one mode to another must be triggered by specific observations or combinations of observations already identified as triggering factors or triggering scenarios (Figure 22.2., Table 22.5).

Trigger 1:

- Changes in water temperature, hydrography, chlorophyll etc. (e.g. registered using remote sensing data as part of an early warning system);

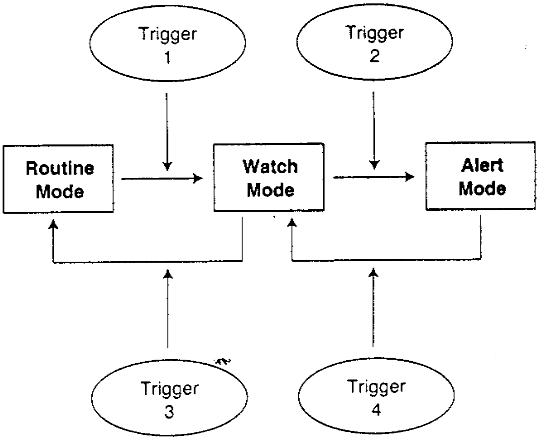

Figure 22.2
Generic action plan with 3 different monitoring modes including examples of triggering factors/scenarios responsible for change of monitoring modes.

- Algal toxins present but below a given regulatory limit;
- Harmful algal species present e.g. above a concentration considered to be of concern.

Trigger 2:
- Algal toxins above a given regulatory limit;
- Fish behaviour indicates intoxication.

Trigger 3:
- Harmful algae not present or the concentration is below a level considered to be of concern;
- Algal toxins not present.

Trigger 4:
- Algal toxins present but below a given regulatory limit;
- Fish behaviour normal.

TABLE 22.5 An overview of relevant monitoring HAB modes to protect various resources and the associated triggering observations for change in mode

Resource to protect	Triggering observations	Monitoring modes
A. Direct impact on humans		
Shellfish for human consumption	Concentrations of potentially toxic algal species or toxicity trigger changes in monitoring mode and management practice. The concentrations that trigger changes in monitoring mode are species-specific. *Example*: concentrations of *Alexandrium tamarense* exceeding 500 cells l^{-1} or *Karenia brevis* exceeding 5000 cells l^{-1} might result in closure of shellfish harvest.	Watch mode
	Concentration levels of toxins in shellfish/fish meat trigger monitoring mode and management practice. *Example*: 80 µg PSP toxin/100 g shellfish meat should result in closing of harvest, as the shellfish are not considered safe for human consumption.	Alert mode
Fish for human consumption	CFP toxins present critical concentrations in fish meat. Fish are not considered appropriate for human consumption. (At present no official guidelines exist for CFP or other algal toxins in fish meat.)	Alert mode
Drinking water	Freshwater with concentrations of microcystin exceeding 1 µg l^{-1} is not considered appropriate for human consumption (WHO, 1990). (At present no guidelines exist for freshwater produced at desalination plants or for the intake water to the plants.)	Alert mode

TABLE 22.5 *(Suite)*

Resource to protect	Triggering observations	Monitoring modes
A. Direct impact on humans		
Recreational use of coastal waters/lakes/ rivers	Observation of algal blooms/scum is in general considered to impose an increased risk for recreational human users of coastal waters/lakes/rivers (WHO guideline, in prep.). In the case of blooms of *Karenia brevis* and *Pfiesteria* spp. the public is warned.	Watch mode – the public is warned not to swim etc.
B. Economic impact		
Wild fish stocks	Blooms of *Chattonella, Karenia mikimotoi, Karenia brevis, Chrysochromulina* spp., *Heterosigma akashiwo* and other icthyotoxic species.	Watch mode
Aquaculture	In the case of blooms of *Chattonella, Karenia mikimotoi, Karenia brevis, Heterosigma akashiwo, Cocchlodinium polykrikoides, Chrysochromulina* spp. *Chaetoceros* spp. etc. Monitoring/ management practice can be changed in different ways depending on the blooming species and the observed bloom concentrations (see Chapter 24)	Watch mode Alert mode
C. Environmental impact		
Biota/ecosystems	In the case of blooms of *Chattonella, Karenia mikimotoi, Karenia brevis, Chrysochromulina* spp. monitoring of different ecosystem components might be initiated. This might also be the case if oxygen deficiency is observed as a result of non-toxic HABs, e.g. a *Ceratium* bloom	Watch mode
D. Conservation impact		
Endangered/protected species	Blooms of relevant harmful species. In the case of blooms of *Karenia brevis*, Florida manatees might be transferred to sheltered areas	Watch mode or alert mode

In the case of HAB monitoring of shellfish, the occurrence of toxic or potentially toxic species of algae can be used to trigger testing for algal toxins in the shellfish meat, which is the primary parameter used to manage the harvest of shellfish. Furthermore, the occurrence of potentially toxic species can result in increasing the frequency of sampling of algae and shellfish for analysis (Watch mode). If the concentrations of toxic or potentially toxic algae exceed specific concentration limits, shellfish harvesting can be closed in the specific harvest areas (Alert mode). In these cases the monitoring of potentially toxic or toxic species is used as an early warning that algal toxins might soon accumulate in the shellfish in concentrations above the given regulatory limits. This kind of monitoring practice is the case e.g. in Denmark, Norway, New Zealand, Spain and Vietnam (Andersen, 1996; IOC, 2001). Detection of low concentrations of algal toxins (below the critical limit) in shellfish meat can also be used to trigger increased sampling (Watch mode). The observation of algal toxins above critical limits can be used to close shellfish harvest (Alert mode), as is the case in most countries with commercial shellfish harvest (Andersen, 1996; IOC, 2001).

In the case of HAB monitoring in relation to aquaculture of fish/crustaceans, the observation of HAB species in low concentrations might result in a suggestion to fish farm operators to stop feeding their fish (Watch mode), whereas high concentrations might result in the towing of net pens to safer areas (Alert mode). (See Table 22.5 for more examples of triggering observations and Chapters 24 and 25 for more details.)

Forecasts can be made which define risk-zones, such as areas with a high incidence of toxic outbreaks or, conversely, areas where harmful blooms are rare. Site selection of aquaculture facilities often requires careful analysis of long-term monitoring data to identify sites with a low risk of HAB events. Here again, the experience of long-time workers in the monitoring programme can provide valuable justification for avoiding or selecting a particular site.

Each monitoring mode should have an associated action plan. When a monitoring programme is shifting from Normal to Watch mode, only minor adjustments to the monitoring action plan may be required. On the other hand, if the HAB situation is critical, Alert mode monitoring must be initiated and pre-approved action plans (mitigation/control) initiated to protect the resources or minimize damage otherwise caused by the HAB. Action plans are likely to be resource-specific. Action plan elements for shellfish affected by HABs include:

- Increase of sampling frequency and geographical coverage
- Closure of shellfish harvest
- Withdrawal of shellfish from the market, depuration of shellfish before they are used for human consumption
- Communication programmes to inform the public that commercial shellfish might be toxic and that recreational collection of shellfish is prohibited/not advised.

Such action plans are initiated based upon the observation of algal toxins above the given regulatory limits in most countries e.g. in Galicia, Spain, Figure 22.3. The Spanish action plan involves multiple monitoring modes (Plan A–D) which are implemented with the observation of one or several triggering factors such as the detection of toxic species in low concentrations, calm weather conditions etc. In some countries, e.g. New Zealand, Norway and Denmark, closure of shellfish harvest and/or advice to the public not to collect shellfish can also be initiated due to algal concentrations above limits.

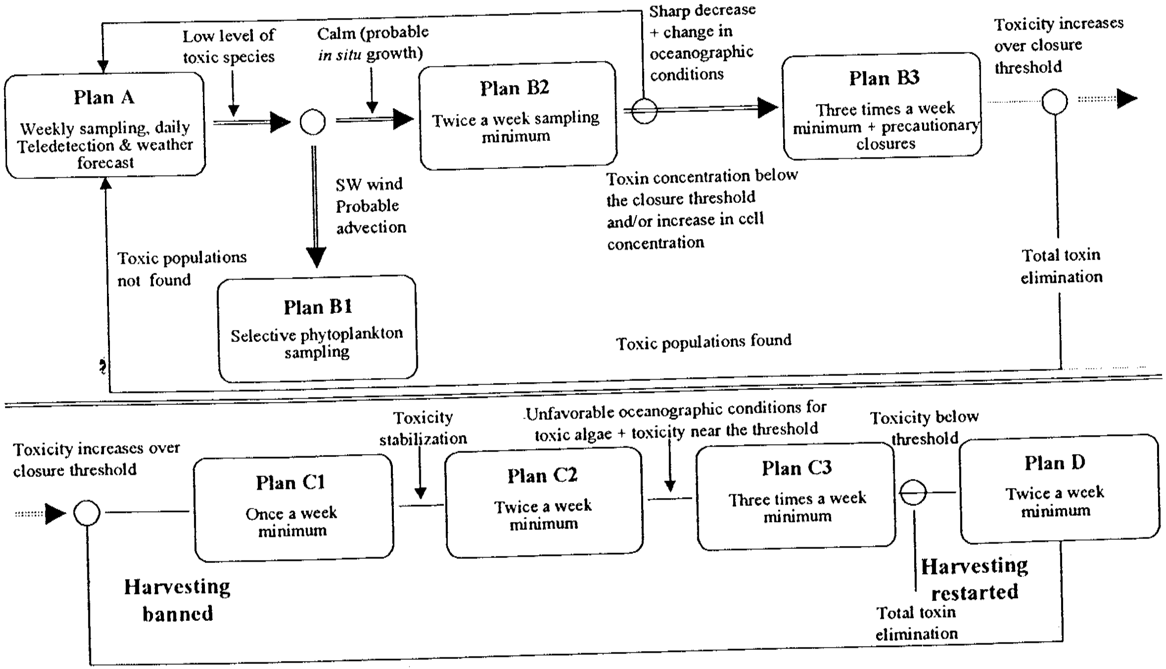

Figure 22.3
Action plan for the biotoxin monitoring programme in Galacia, NW Spain. The different monitoring modes are denoted as Plan A, B, B1 etc. Triggering factors are shown as thin arrows pointing to the lines linking one plan to the next. (Note: the figure starts left at the upper panel and continues at the left of the lower panel, from Mariño *et al.*, 1998.

Action plans for aquaculture operations include a range of mitigation measures such as:

- Stoping feeding the fish
- Preparing for and/or conducting pre-emptive harvest
- Moving the culture pens into waters with less risk of HAB
- Applying perimeter skirts to culture pens
- Aeration
- Potentially suppressing the HAB by adding materials to disperse or suppress the algal bloom (e.g., clays, or other, see Chapter 25).

Action plans for recreational use of coastal waters include measures such as:

- Advising the public to stay out of the water
- Advising the public to shower properly following swimming during certain types of HABs
- Advising the public to avoid inhaling sea spray.

Action plans to rescue/save endangered/protected species from HABs may include measures such as:

- Ill or affected animals can be transferred to protected areas during HABs
- Bloom mitigation measures (e.g., clay dispersal) if the situation is severe and the resource to be protected is sufficiently important.

Action plans for protection of the general environment from the effects of HABs usually do not include short-term measures, but may include actions such as minimizing the run-off of nutrient-rich water from land (eutrophication) which, in the long term, may reduce the risk of certain types of HABs.

22.2.3 Distribution of information to users

After appropriate quality assurance, data and results can be distributed to the users of the monitoring programme by telephone, telephone answering machine, fax, e-mail and the Internet. The use of the Internet to distribute HAB monitoring data is common in many countries/regions, e.g. in Denmark, Germany, Norway, Hong Kong SAR, Ireland, Italy, Sweden, and USA. Most of these web pages contain general information on HABs as well as updated information on the current algal situations. Some pages also include recommendations to recreational shellfishermen and information on the present situation of the commercial shellfish harvest. Geographic information system (GIS) tools can be very useful to present and evaluate HAB information. Additionally it is highly recommended that status reports be made available on local/global networks or as easily accessible reports on the Internet.

Public information is a natural part of a HAB action plan. Information material should be available and communication strategies involving different media (TV, radio, newspapers, Internet, callers, posters, booklets etc.) should be prepared.

22.2.4 Organization and structure of HAB monitoring programmes

The structure of a HAB monitoring programme can become rather complicated depending upon the number of institutions involved in the individual analysis procedures at each level in the network. Nevertheless, the structure of HAB monitoring programmes must be kept as simple as possible to facilitate a rapid and uncomplicated flow of information between the individuals and institutions involved. Responsibilities for specific elements of the programme must be clear to all individuals involved.

The operational structure should be well documented in the form of a report distributed to all users, containing information on which institutions are involved (addresses, phone and fax numbers, e-mail addresses etc.), the responsible persons in the different institutions (addresses, phone and fax numbers, e-mail addresses etc.) and a clear description of which tasks each institution/person is responsible for. This report should be periodically reviewed and updated.

In most cases (85%) of the existing HAB monitoring systems, the institution/organization that initiates a HAB monitoring programme is also responsible for carrying out the monitoring operations (Andersen, 1996). In some cases the management structure as well as the conduct of the HAB monitoring programmes is advised by or has to refer to a task force if the programme is to be changed. This is the case in New Zealand, where the Marine Biotoxin Management Board must confirm and approve any changes in the HAB monitoring system, whereas in Denmark a HAB task force under the Veterinary Service discusses relevant issues and suggests changes in the monitoring and management procedures which subsequently must be approved by the Veterinary Service. If an unusual HAB occurs in Danish waters, the Danish HAB task force will be summoned to discuss the current situation and give advice to the Veterinary Service on what to do. This kind of administrative unit for technical advice is also currently part of the Japanese, Hong Kong, and Philippine HAB management system. In Japan a 'Consultative Committee' provides the technical advice, whereas it is called 'National Red Tide Committee' in the Philippines (Andersen, 1996; Anderson, *et al.* 2001).

Most HAB monitoring programmes rely on different official authorities and/or universities for sampling of algae and shellfish for toxicity analysis (Andersen 1996, IOC 2001). Private consultancy companies can also be involved in HAB monitoring programmes. For example, in the state of California, sampling of algae and shellfish is carried out at fixed stations at weekly intervals by local companies, organizations etc. on a voluntary basic under the guidance of the State of California Department of Health Services, which is also responsible for analysing the samples. In Denmark the fishermen carry out the sampling of algae and mussels, and private consultancy companies analyse those samples. The consultancy companies report to the Ministry of Food, which is responsible for the management decisions (Andersen 1996).

As the organization of a HAB monitoring and management programme depends heavily on the country-specific structures it has to interact with and depend on, it is difficult to provide a generic description here. Figure 22.4 illustrates a hypothetical master plan for a HAB monitoring and management programme.

The complex monitoring/management structure for a multi-resources management system (Figure 22.4) is designed to co-ordinate HAB monitoring in relation to a whole range of resources including fish (wild, aquaculture and imported), shellfish (wild, aquaculture and imported), recreational/tourist aspects, environmental impact and conservation impact. The generic master plan relies on co-operation and co-ordination of the monitoring and management effort carried out by a range of government agencies. Furthermore it assumes that observational information can be obtained from fish farmers and other participants as well as from neighbouring countries or regions. An Operational Technical Team (OTT) composed of technical representatives of the involved agencies collects all monitoring information. The OTT is responsible for initiating action plans and changing of monitoring modes. A HAB Task Force (composed of higher-level officials in the relevant agencies) must agree with any changes in the monitoring programme. The

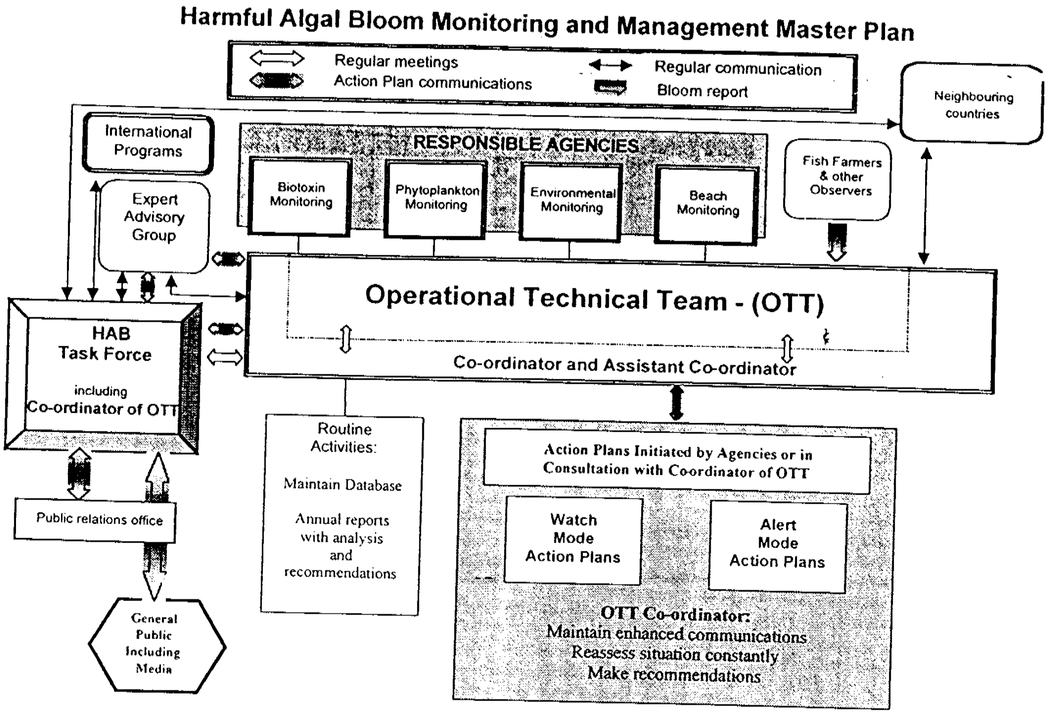

Figure 22.4
One hypothetical structure for a multi-resource HAB monitoring programme.

HAB Task Force can consult the Expert Advisory Group for scientific/technical advice. All public information is to be communicated by a selected member of the HAB Task Force in cooperation with the relevant public relations office to minimize confusion during a HAB. If more than one member or agency communicates to the public, confusion can often occur, so it is best to assign this role to a single, well-informed individual.

The following examples are offered to demonstrate the management structure used in Denmark and Norway. See Chapter 23 for a detailed case study from New Zealand.

Example 1. *Simple monitoring/management structure of one single resource.* The Danish HAB monitoring programme for Danish mussel fisheries is constructed to manage HABs in relation to a single resource – wild stocks of mussels (Figure 22.5). The official regulations concerning sampling and quantification of toxic phytoplankton and algae toxins in relation to the Danish mussel fisheries are given in European Union order no. 202 'Laying down the health condit ons for fishery, handling, production and placing on the market of bivalve molluscs, 15 April 1993' and the guidelines no. 7000 of 27 April 1993 and no. 13220 of 28 February 1995. The Danish legislation implements the EEC Council Directive of 15 July 1991 'Laying down the health conditions for the production and the placing on the market

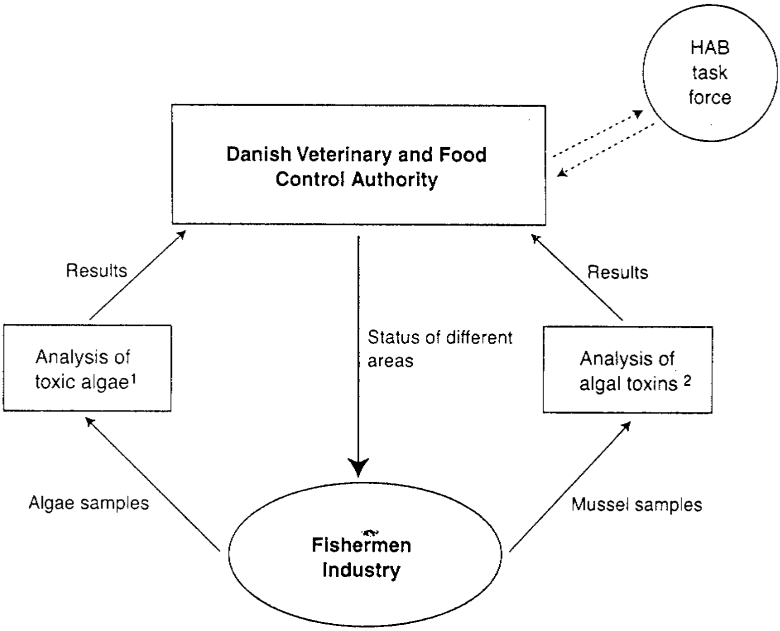

Figure 22.5
The structure of a simple single-resource HAB monitoring programme — The Danish HAB monitoring programme in relation to the Danish mussel fisheries.

of live bivalve molluscs', 91/492/EEC, with later amendments. The monitoring programme works as follows. Samples of algae and mussels are collected by the fishermen and are sent to private consultancy laboratories. The results of the analysis are forwarded directly by the laboratories to the Danish Veterinary and Food Control Authority, which inform the fishermen and industries on the status of each fishing area. At least once a year the Danish HAB task force meets to review the on-going monitoring and management procedures and to exchange new findings nationally and internationally. The Danish Veterinary and Food Control Authority implements the recommendations of the HAB task force. The monitoring programme is not coordinated with, nor does it rely on information from other Danish monitoring programmes, but data are exchanged between the local environmental authorities and the HAB monitoring programme.

Example 2. *A multi-resource monitoring/management structure.* The Norwegian HAB monitoring programme is designed to protect the significant marine aquaculture enterprises, shellfish cultures as well as recreational collection of shellfish. The monitoring programme covers most of the coastal waters and fjords of Norway. Information on the occurrence of HABs is gathered from different sources such as a "fish farm observation network" covering 40 sites along the Norwegian coast, including fish farmers, aquaculture research stations, lighthouses and mussel farmers. A total of 80 stations are currently sampled in Norwegian coastal waters, covering the Norwegian coastline from the Swedish border in the South to the Russian border in the North. Samples for monitoring of harmful algae are collected weekly by a number of fish farmers, mussel farmers and the Norwegian Food Control Authority as well as research institutions. If algal concentrations are high, based upon Secchi disk transparency measurements and watercolour, fish farmers will collect additional samples. Guidelines for sampling as well as Secchi depth measurement are provided to the fish farmers. Furthermore, the Norwegian Food Control Authority, as well as offshore moorings known as SEAWATCH-buoys, collects oceanographic data.

All data are collected and compiled by a consultancy company, which is responsible for advising fish farmers if an HAB should occur. The shellfish data are evaluated by, and are available from, the Norwegian Food Control Authority. Furthermore the complete data set is used to evaluate the HAB situation in Norwegian coastal waters on a weekly basis and the result of the evaluation is published on the internet as 'Algeinfo' by the Institute of Marine Research in co-operation with the consultant, the Ministry of Fisheries, and the Norwegian Institute for Water Research (Figure 22.6).

In the Norwegian programme, it is considered very important that the fish farmers themselves take immediate action if a fish-killing bloom is reported in an area, or if they observe the fish beginning to behave abnormally. The action that must be taken to reduce losses involves different mitigation measures, which are carefully planned and tested in advance.

In the case of shellfish, the Norwegian Food Control Authority regulates the harvests from specific aquaculture sites and the public is informed on the HAB situation and the risk of collecting toxic shellfish via the 'Algeinfo' web page as well as through a web page run by the Norwegian Food Control Authority.

The Norwegian monitoring programme is periodically revised based upon experience in Norway and internationally. Over the years, revisions have involved moving sampling stations and/or increasing the number of stations to improve the coverage of the monitoring, as well as updating and adding new names to the list of HAB species in Norwegian waters.

22.3 Improving HAB Monitoring and Management

To improve existing or future HAB monitoring and management and the related action plans, systematic collection of qualitative and quantitative data on the occurrence of HAB species, the algal toxins and effects of HABs, as well as epidemiological studies are needed. Based on such data sets the monitoring effort can be optimized with respect to its ability to actually forecast/detect developing HAB events, the effectiveness of management and mitigation during HAB events, and cost efficiency. Furthermore, improved data acquisition and analysis are pre-requisites for future improvements of HAB forecasts and control. This might include using satellite remote sensing data, in-situ buoy measurements in combination with physical and biological modelling, as well as improved analysis and evaluation of the data available to identify potential bloom scenarios and bloom triggers. This often goes beyond the resources and mandate of national monitoring programmes. This is why basic research is often necessary to support and augment monitoring programmes.

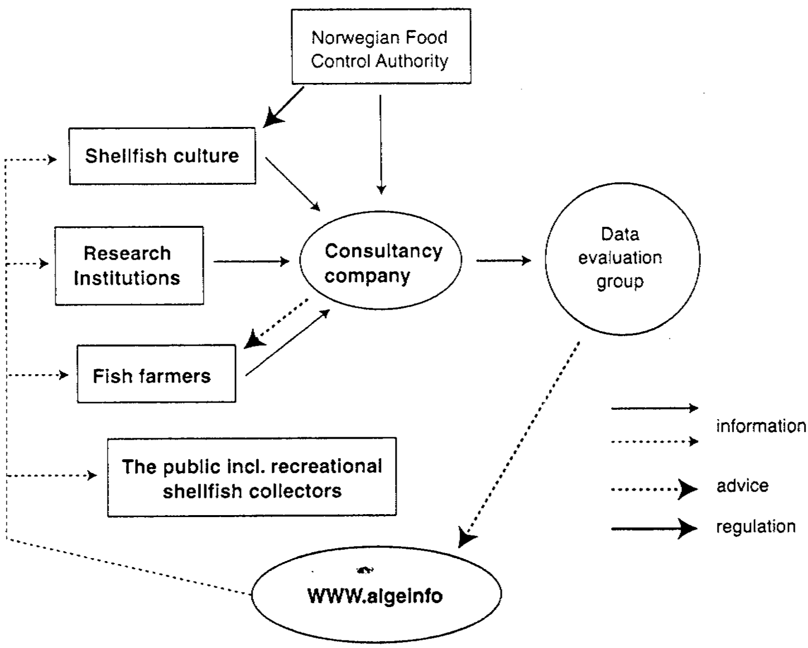

Figure 22.6
The structure of the Norwegian multi resource HAB monitoring programme covering marine fish farms and shellfish cultures as well as recreational collection of shellfish.

At the international level, research programmes such as GEOHAB have established the goal to improve our ability to predict and thereby improve HAB management and mitigation GEOHAB, 2001).

Other aspects, which require regional and international monitoring cooperation, are the potential spreading of HAB species over long distances via ballast water of ships, with live seafood, etc., and the cross territorial effects of cultural eutrophication, which can be of importance especially for the high biomass HAB species. Coordination within countries/regions as well as coordination/sharing of information between countries/regions is also important because HABs are phenomena that

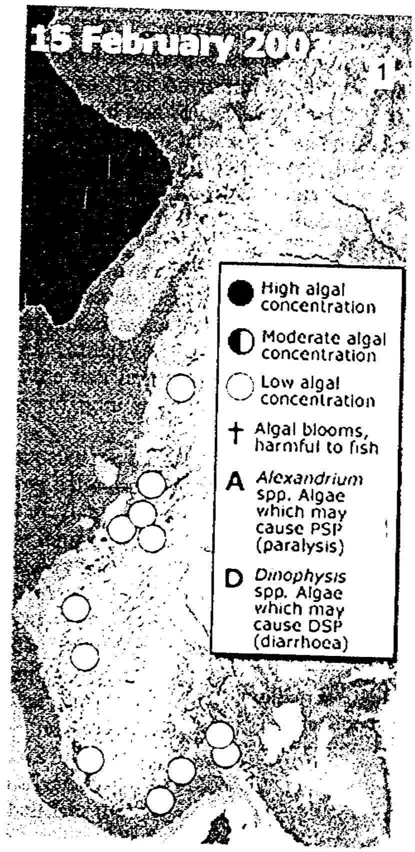

Figure 22.7
Map from the Norwegian Internet Homepage 'Algeinfo' showing the sampling locations and a legend box explaining the different symbols used on the map. Note that the map is from a winter situation (February 2002) where no HABs occurred.

cross territorial boundaries. Local management plans may become even more efficient and able to provide an early warning if exchange of information and data are facilitated across national or regional borders.

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