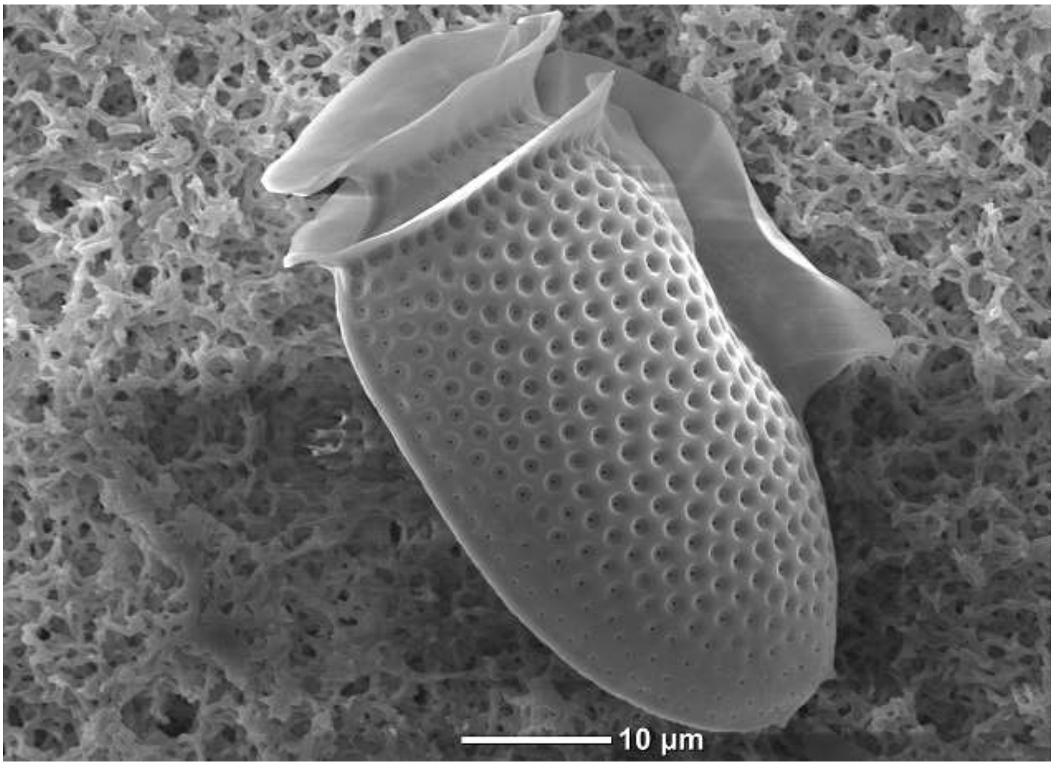
Manx Marine Environmental Assessment

Ecology/Biodiversity

Plankton in Manx Waters



Scanning Electron Microscope image of *Dinophysis acuminata* (a toxic dinoflagellate).
Photo: K. Kennington - Government Laboratory. Department of Environment, Food and Agriculture.

MMEA Chapter 3.1

October 2018 (2nd Edition)

Lead author:
Dr Kevin Kennington – Government Laboratory, Dept. of Environment, Food and Agriculture

Manx Marine Environmental Assessment

Second Edition: October 2018

This document was produced as part of the Manx Marine Environmental Assessment, a Government project with external stakeholder input, funded and facilitated by the Department of Infrastructure, Department for Enterprise and Department of Environment, Food and Agriculture.

This document is downloadable from the Department of Infrastructure website at: https://www.gov.im/about-the-government/departments/infrastructure/harbours-information/territorial-seas/manx-marine-environmental-assessment/

Contact:
Manx Marine Environmental Assessment
Fisheries Division
Department of Environment, Food and Agriculture
Thie Slieau Whallian
Foxdale Road
St John's
Isle of Man
IM4 3AS

Email: fisheries@gov.im
Tel: 01624 685857

Suggested Citations:
Chapter
Kennington, K. 2018. Plankton in Manx Waters. In: Manx Marine Environmental Assessment (2nd Ed). Isle of Man Government. pp 22.

Contributors to 1st edition:
Dr Kevin Kennington – Government Laboratory, Department of Environment, Food and Agriculture

Disclaimer:
The Isle of Man Government has facilitated the compilation of this document, to provide baseline information on the Manx marine environment. Information has been provided by various Government Officers, marine experts, local organisations and industry, often in a voluntary capacity or outside their usual work remit. Advice should always be sought from relevant contacts where queries arise.

The editors have taken every care to ensure the accuracy of the information contained but accept that errors and omissions may be present. The editors accept no responsibility for the accuracy or currency of information provided on external sites.

All MMEA chapters may be amended and improved upon in light of new information or comments received. As such, all chapters should be considered as working documents.
Any initial guidelines or recommendations within the document are provided to help facilitate future discussions between stakeholders, Government Departments, future developers and the general public, and should be read only in the context of the document as a whole. This document does not provide legal or policy advice but rather a statement of known information about Manx territorial waters.

The mapping detail contained in this document is subject to the limitations of scale and depiction of any feature, does not denote or infer right of way and no claim is made for the definitive nature of any feature shown on the mapping. New marine datasets created for the project have not been subject to formal verification.

Plankton of the Manx Territorial Sea

Introduction

It would be impossible to discuss the hydrography, nutrient cycles and plankton community dynamics of the Manx territorial sea without making reference at least, to the Irish Sea as a whole. The transient or Lagrangian nature of waters around the Isle of Man mean that they are influenced by factors operating outside of Manx territorial waters. The net movement of water in the Irish Sea is northwards. Waters within the territorial sea are not only influenced by conditions in the open Atlantic but also by factors such as urban run-off and riverine discharges entering the Irish Sea from outside territorial waters. It is for this reason that this chapter draws heavily on information from across the Irish Sea basin as well as from the Manx territorial sea.

As a small nation the Isle of Man has been extremely fortunate in that scientific research and monitoring of the marine environment has been undertaken over a great many decades. As far back as late Victorian times, enthusiastic amateur and professional marine scientists regularly visited the Island to undertake fieldwork in the Island's relatively pristine waters. Eventually such enthusiasm became the precursor for Professor Herdman to establish a Marine Laboratory in Port Erin. Some of the measurements and time-series mentioned in this section have their origins back in the first decade of the last century and were started by Professor Herdman himself.

The importance of these time-series cannot be over-emphasised as it is only by comparing recent data with data collected over many decades that natural change can be discerned from anthropogenic changes. The data from the time-series are internationally renowned and have been quoted in dozens of international peer reviewed publications and scientific reports over the last few decades. These publications have dealt with subject matter ranging from pollution ecology through to global climate change.

After the closure of the Port Erin Marine Laboratory in 2006 it was inevitable that certain monitoring programmes would come to an end. However, some of the most important time-series of their kind, such as the Cypris station's long-term monitoring programme and the environmental time-series collected in Port Erin Bay were taken over by the Isle of Man Government and continue to this day.

Drivers

The government of the Isle of Man is a signatory to a number of EEC and international drivers designed to protect the marine environment and ensure food products harvested from the territorial sea are fit for human consumption, these include;

- Shellfish Hygiene Directive
- Shellfish Waters Directive
- Bathing Waters Directive

- Oslo-Paris Convention on the Protection of the Marine Environment of the North East Atlantic (OSPAR)
- UN Convention on Biological Diversity

Additionally the recent EEC Marine Strategy Framework Directive (MSFD), which calls on member states to ensure all marine waters achieve good environmental status by 2020, means that the Isle of Man Government is required to work closely with the neighbouring governments of the United Kingdom. The MSFD is the environmental pillar of the Integrated Maritime Policy (Com (2007) 575) which includes trans-boundary issues that require cooperation and collective action with regard to maritime resource conservation and exploitation.

Site Locations

Regular monitoring of a suite of variables is undertaken at six locations around the Isle of Man. The variables monitored at these stations include nutrients, salinity, temperature, chlorophyll, phytoplankton and dissolved oxygen (see chapters on Marine Pollution and Physical Marine Environment for more info on these variables). Figure 1 show the location of these positions and Table 1 gives the approximate positions of the five offshore stations. The sixth long term monitoring station is at Port Erin Bay where data loggers are installed on the life-boat slip.

Table 1. Locations of offshore monitoring stations around the Isle of Man.

Station Name	Location	Latitude	Longitude
Cypris	Port Erin (Bradda)	54°05.50	04°50.00
Targets	Jurby	54°21.50	04°38.00
Ramsey	Ramsey	54°20.47	04°17.47
Laxey	Laxey	54°12.00	04°23.00
Resa	Santon	54°05.00	04°30.00

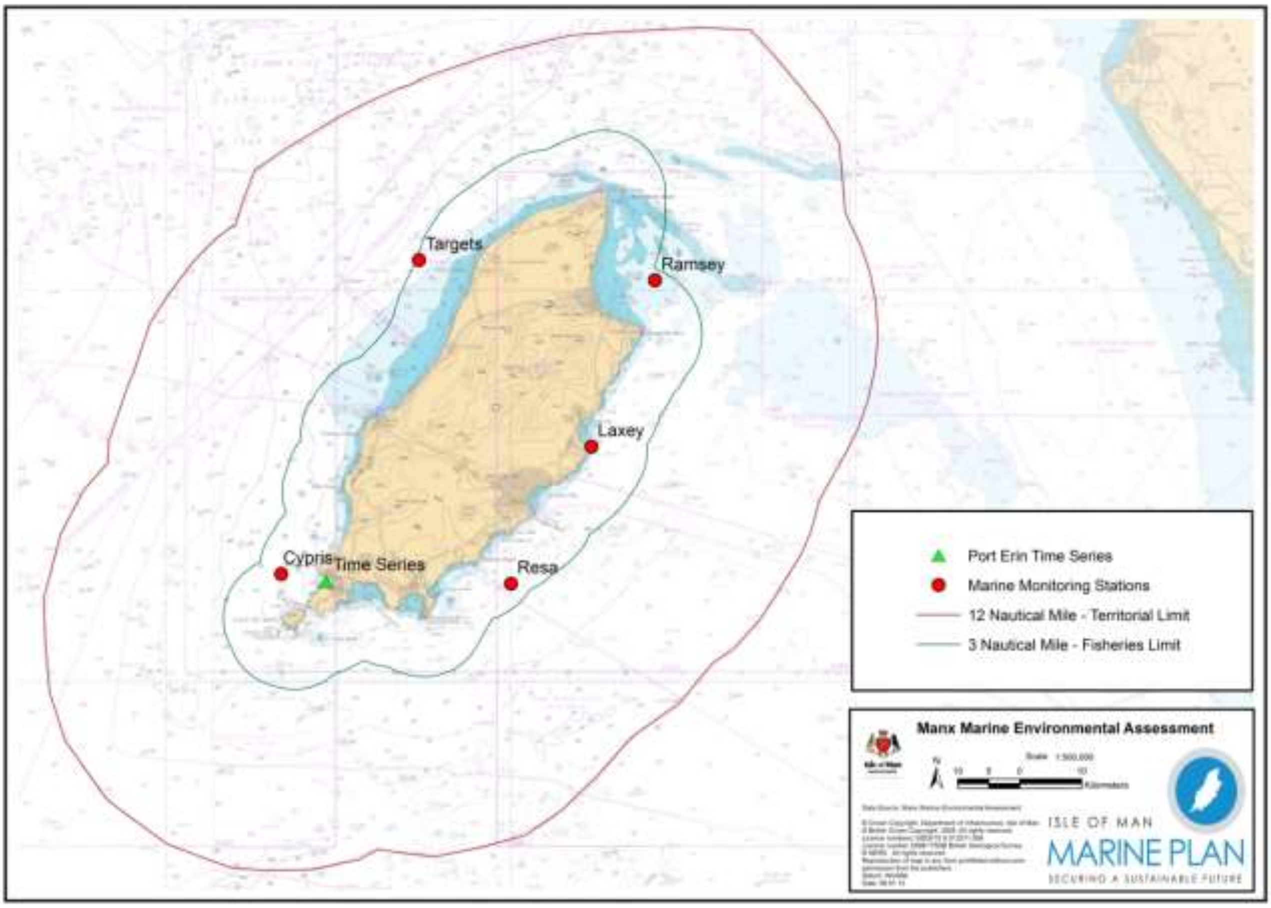


Fig 1. Location of monitoring stations around the Isle of Man.

Plankton in Manx Waters

Phytoplankton

It is beyond the scope of this report to comment on the community analysis of phytoplankton in Manx waters which are typical of open Irish Sea waters as a whole, further information on phytoplankton community structure of the Irish Sea can be found in the following publications and references therein (Gowen and Stewart (2005), Gowen *et al.* (2008), Gowen *et al.* (2011) Kennington *et al.* (1999, 2004), Kennington and Rowlands (2006), Montagnes *et al.* (1999).

Phytoplankton Seasonality

Phytoplankton seasonality within the Manx territorial sea is typical of that found for northern temperate waters as a whole. Chlorophyll *a* is a proxy indicator of phytoplankton biomass, Figure 2 shows the chlorophyll *a* data recorded from the Cypris station between 1966 and 2011. It can be seen that phytoplankton biomass is low during the winter months with chlorophyll *a* concentrations being generally below 1µg/litre. As daylight becomes longer and temperatures begin to increase during the spring months, phytoplankton production increases rapidly, a phenomenon known as the spring bloom. The spring bloom in Manx waters is generally dominated by diatoms and microflagellates. As the spring and summer months progress there is a distinct succession of phytoplankton functional groups. During the spring bloom both nitrate and silicate rapidly become exhausted as the diatom flora (which require silicate for growth of their frustules) dominate. After this time the diatom population readily crashes and is replaced by the dinoflagellate population which becomes dominant during the summer and autumn months.

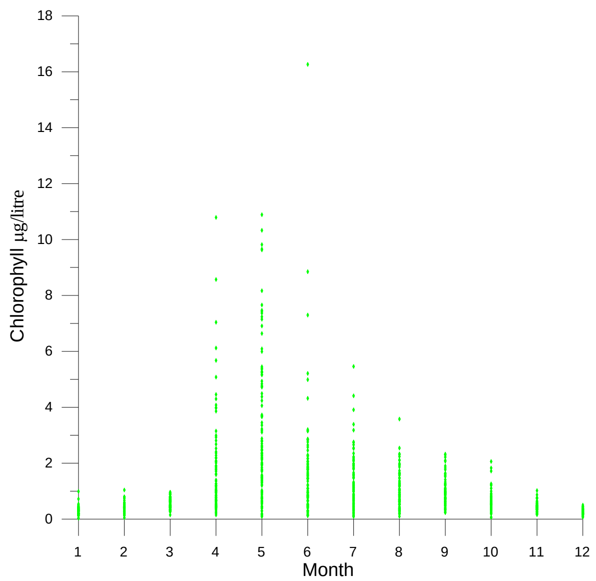


Figure 2. Seasonality of chlorophyll *a* concentrations recorded at the Cypris station (1966-2011).

Nuisance and Toxic Phytoplankton

Certain species of phytoplankton can produce toxins which are harmful to human health, whilst others can form blooms which are so dense that they can cause disruption to the marine ecosystem. The Manx Territorial Sea and the Irish Sea as a whole has many species which are either toxic or bloom forming. Regular monitoring of toxic and nuisance algal species is conducted by the Isle of Man Government Laboratory at several locations around the Isle of Man. Table 2 shows the major toxic and nuisance algal species recorded from the Irish Sea and Manx coastal waters as part of regular monitoring programmes.

Table 2. Toxic and nuisance algae recorded from the Irish Sea (note PSP =Paralytic Shellfish Poison, ASP = Amnesic Shellfish Poison, DSP = Diarrheic Shellfish Poison).

Species	Comment	Recorded
Alexandrium spp. (Dinoflagellata)	Associated with PSP toxins	Manx coastal waters, Eastern Irish Sea
Alexandrium catenella	Associated with PSP toxins	Manx coastal waters, Irish Sea,
Chaetocerous spp. (Bacillariophyceae)	Can irritate fish and invertebrate gill structures.	Manx coastal waters, Irish Sea
Dictyocha speculum (Dictyochophyceae)	Can irritate fish and invertebrate gill structures.	Manx coastal waters, Irish Sea
Dinophysis acuminata (Dinoflagellata)	DSP producer	Manx coastal waters, Irish Sea
Dinophysis acuta (Dinoflagellata)	DSP producer	Manx coastal waters, Irish Sea
Heterosigma akashiwo (Raphidophyceae)	Haemolytic and ichthyotoxic Can cause fish kills	Irish Sea
Karenia mikimotoi (Dinoflagellata)	Haemolytic and ichthyotoxic Can cause fish kills	Manx coastal waters, Irish Sea
Lingulodinium polyedra (Dinoflagellata)	Homoyessotoxin producer	Manx coastal waters, Irish Sea
Noctiluca scintillans (Dinoflagellata)	Can form dense blooms	Manx coastal waters, Irish Sea
Phaeocystis spp. (Prymnesiophyceae)	Can form dense blooms	Manx coastal waters, Irish Sea
Phalocroma rotundata (Dinoflagellata)	DSP producer	Manx coastal waters, Irish Sea
Prorocentrum lima (Dinoflagellata)	DSP producer	Manx coastal waters, Irish Sea
Prorocentrum micans (Dinoflagellata)	Can form dense blooms	Manx coastal waters, Irish Sea
Prorocentrum minimum	Venerupin toxin, ichthyotoxin	Irish Sea
Pseudo-nitzschia spp. (Bacillariophyceae)	ASP producer	Manx coastal waters, Irish Sea
Protoperidinium spp. (Dinoflagellata)	Can form dense blooms	Manx coastal waters, Irish Sea
Myrionecta rubra (Photosynthetic ciliate)	Can form dense blooms	Manx coastal waters, Irish Sea
Ceratium fusus (Dinoflagellata)	Can harm invertebrates	Manx coastal waters, Irish Sea
Oxyrrhis marina	Can form dense blooms	Manx coastal waters, Irish Sea. (often found blooming in rock pools on the IOM)

Whilst most of the species noted in Table 2 do not occur in concentrations likely to be problematic, certain taxa have been responsible for elevated levels of shellfish toxins in Manx coastal waters. Of note are the *Dinophysis* species (cover image), which are associated with DSP toxins, these species are common during the spring and summer months around the Island and have regularly exceeded threshold levels in Manx waters.

Whilst PSP producing organisms such as *Alexandrium* spp. are rarely encountered in Manx waters they have been recorded from elsewhere in the Irish Sea, and it is therefore important that monitoring programmes check for the presence of these taxa.

The unarmoured dinoflagellate *Karenia mikimotoi* (aka *Gyrodinium aureolum, Gymnodinium aureolum, Gymnodinium nagasakiense, Gymnodinium mikimotoi*) has also been recorded from the Irish Sea. This species has been known to form extensive blooms such as that which occurred along the west and northern coasts of Scotland during 2006 (Davidson et al*.* 2009). This species has been associated with the mass mortality of both fish and benthic fauna.

Other non-toxic algae such as *Phaeocystis* species and *Noctiluca scintillans* have formed dense blooms in Manx coastal waters. *Phaeocystis* blooms tend to occur in the spring and early summer. The species often produces extracellular substances resulting in dense foam production under wave action. It is the deposition of these foams on beaches which are the manifestation of the nuisance of this species. *Noctiluca scintillans* has also caused spectacular blooms around the Isle of Man which can turn the seawater as red as 'tomato soup'. Whilst neither of these species are thought to produce toxins, they could be responsible for a localised reduction in bottom-water oxygen concentrations, as a result of bloom degradation, with the resultant mortality of sessile benthic organisms.

Pseudo-nitzschia species which are associated with domoic acid (DA) production, a causative agent of ASP are also commonly recorded from water samples and can represent a significant component of the diatom community in Manx coastal waters. Elevated concentrations of DA have been recorded from the King Scallop (*Pecten maximus*) fished from Manx waters (Bogan et al. 2007) and it is highly likely that *Pseudo-nitzschia* was responsible. The Manx king scallop fishery has been severely impacted by domoic acid toxicity on at least three occasions in recent years (2006, 2009 and 2014). Whilst not the most toxic of phycotoxins, domoic acid currently represents the biggest phycotoxin threat (both economic and environmental) to the shellfish industry in the Isle of Man.

Seasonality of Toxic Algae in Manx Waters

The Isle of Man Government's laboratory undertakes routine analysis of phytoplankton collected from the Manx territorial sea as part of a shellfish toxin monitoring program. Monthly data gathered between 2011 and 2017 has been used to highlight the seasonal profiles of the most common toxic genera associated with shellfish poisoning.

***Pseudo-nitzschia* species**

It can be seen from Figure 3 that *Pseudo-nitzschia* species (recorded as either *P. seriata* complex or *P. delicatissima* complex) are most abundant between May and August with a seasonal peal during June. Pseudo-nitzschia species are present in Manx waters throughout the year albeit in low abundances between October and March, they are not known to form auxospores.

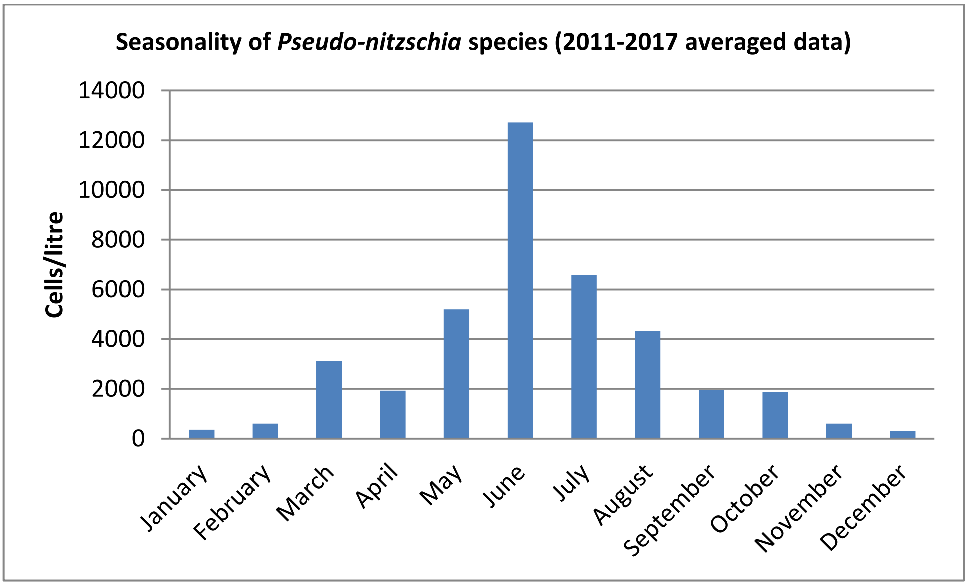


Figure 3. Seasonality of *Pseudo-nitzschia* species (2011-2017 averaged data).

***Dinophysis* species**

Several species of *Dinophysis* are regularly recorded from Manx waters including *D. accuminata, D. acuta, D. norvegicus, D. saculus* and *Phalachroma rotundata*. All of these species have been shown to produce toxins associated with diarrhetic shellfish poisoning such as Okadaic acid & the Dinophysis toxins (DTX-1-3).

Figure 4 shows the seasonal cycle of all *Dinophysis* species identified via the Manx Government's marine monitoring program. It can be seen that the species are most abundant between March and August. Peak abundances occur in July and previous studies have shown the genus to be associated with the thermocline in the western Irish Sea.

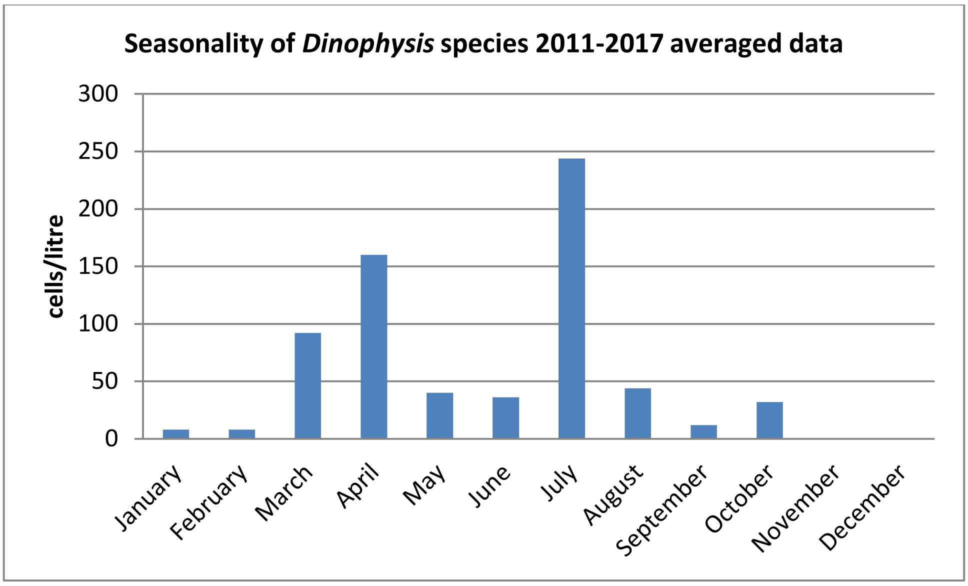


Figure 4. Seasonality of *Dinophysis* species in Manx waters (2011-2017 averaged data).

***Alexandrium* species**

Several species of the armoured dinoflagellate genus *Alexandrium* have been shown to produce the Paralytic Shellfish Poison (PSP) saxitoxin, the same toxin associated with the puffer fish or Fugu (Tetraodontidae). *Alexandrium* species are very hard to identify to species level with standard light microscopy and not all *Alexandrium* species are toxic. It is therefore as yet unknown as to whether the species identified under the Manx Government's monitoring program represent toxic or non-toxic strains of this genus. To date no saxitoxins have been recorded from scallops caught and analysed on the Island which may suggest that the species found in Manx waters are predominantly of the non-toxic variety.

Figure 5 shows the seasonal profile of *Alexandrium* species from Manx waters. It can be seen that the species is only recorded between March and September (with maximum occurrences in July & August) and is absent from Manx waters during the winter months. The genus is known to produce cysts capable of overwintering in sediments and it may be that it is this strategy that accounts for the absence of adult forms during the winter months.

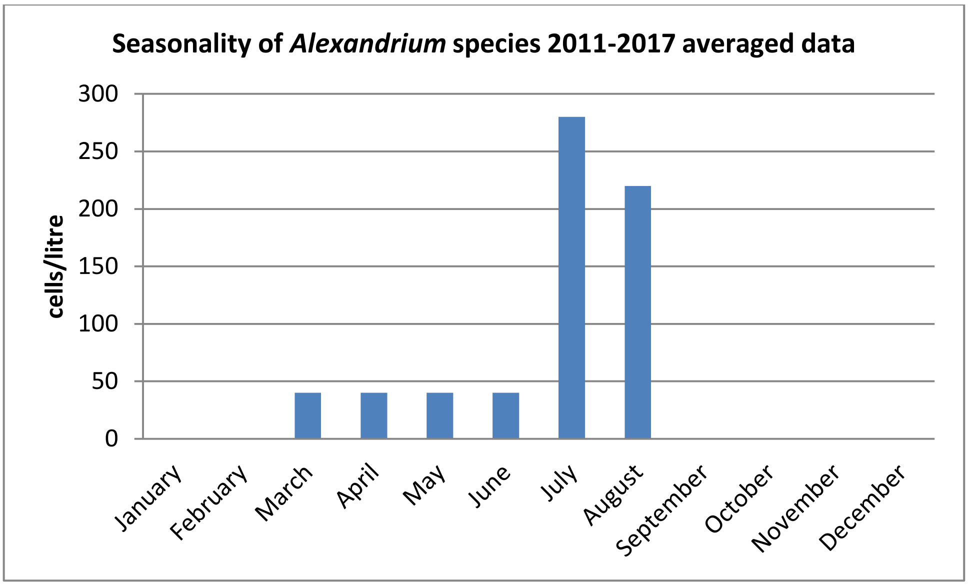


Figure 5. Seasonality of *Alexandrium* species in Manx waters (2011-2017 averaged data).

Case Study: The 2014 *Pseudo-nitzschia* bloom and domoic acid intoxification of king scallops.

The marine diatom genus *Pseudo-nitzschia* contains several species which produce the phytoxin domoic acid. Domoic acid (DA) is the principle toxin responsible for amnesic shellfish poisoning (ASP). Bi-valve molluscs such as scallops are passive filter feeders and can consume these toxic algae and concentrate the toxins in their flesh. In extreme events ASP can disrupt ecosystems and kill higher animals (including humans) that eat food contaminated with the toxin.

The Isle of Man Government Laboratory's routine sampling program first detected elevated concentrations of *Pseudo-nitzschia* cf *seriata* in May 2014 to the south and west of the Island. Highest concentrations (~60,000 cells/litre) were counted from surface waters at the Cypris station in early June 2014 (Figure 6). Elevated counts at this location lasted until mid-June. Further to the north at the Targets monitoring station, counts were not as high as those reported for the Cypris station but the bloom lasted longer. The bloom development at these two locations was coincidental with a very dense bloom of the diatom *Chaetoceros socialis.*

The bloom dynamic was different between east and west coast stations in that the records suggest that the east coast population (Ramsey and Resa stations) developed slightly later and was not associated with high concentrations of *C. socialis.*

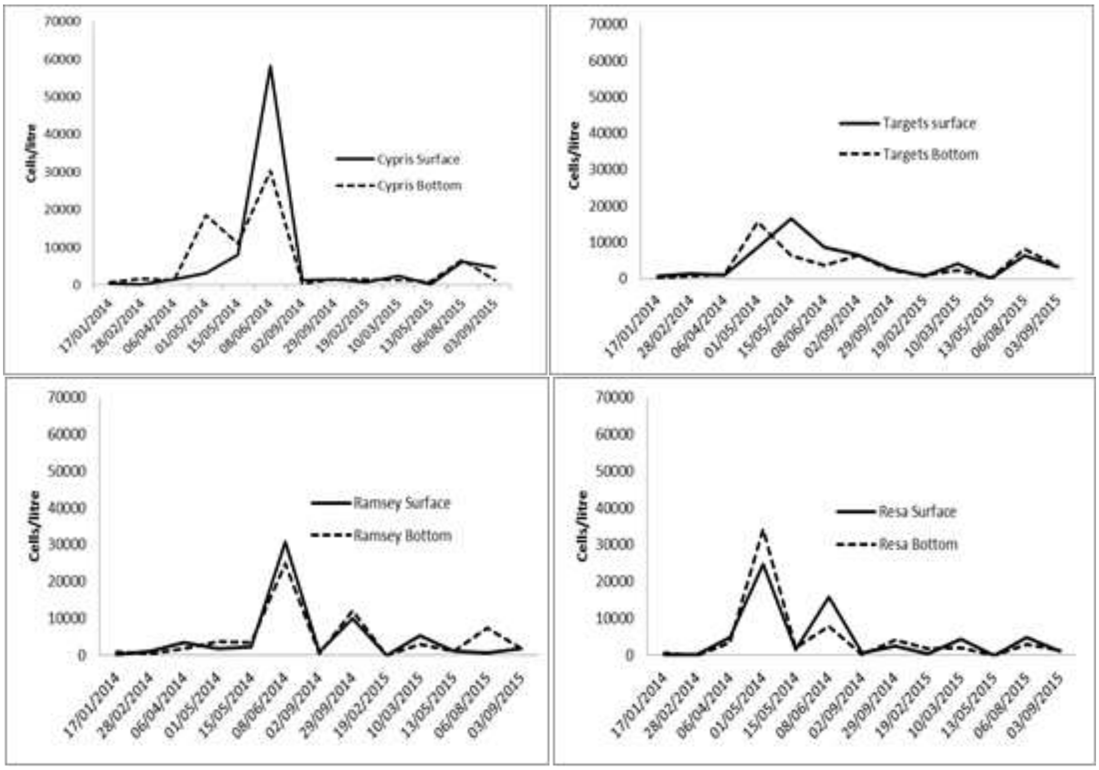
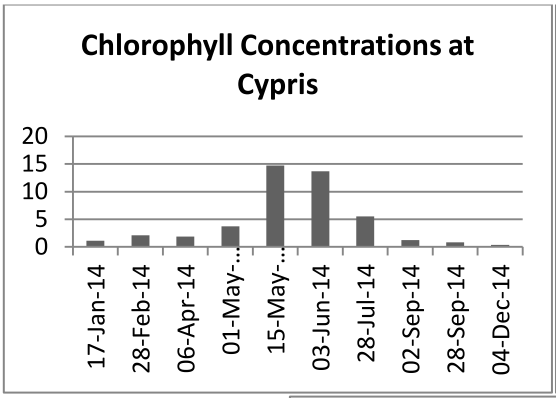


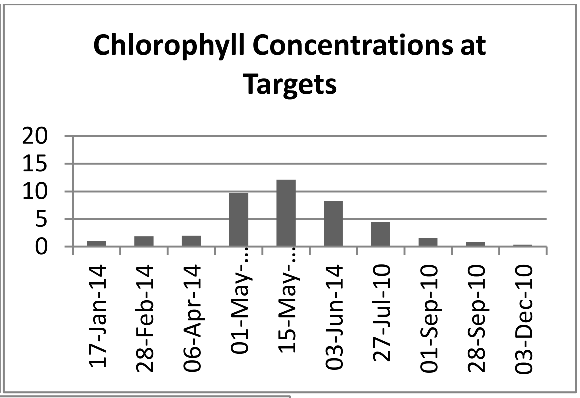
Figure 6. *Pseudo-nitzschia* cf *seriata* counts (as cells/litre) at four monitoring stations around the Isle of Man in 2014/15 (solid line surface waters, dashed line bottom waters).

The high concentrations of *Chaetoceros socialis* on the west coast contributed significantly to the phytoplankton biomass in these waters during the spring of 2014. This is reflected in the chlorophyll analysis which shows peak chlorophyll concentrations at the Cypris station and Targets station to be 15 µg/l & 12 µg/l respectively. Chlorophyll concentrations along the east coast were much reduced (<5 µg/l) throughout the study period (Figure 7).

Data from satellite remote sensing using the Modis Aqua chlorophyll channel suggests the bloom first appears in surface waters to the west of Peel between the 21st and 27th May before tracking north and south along the coast and eventually moving offshore to the west. The bloom at its peak covers an area of approximately 40x20 nM. The bloom lasted for approximately six weeks and is not seen in satellite images after 17th June 2014. The satellite data does not show any significant increase in phytoplankton biomass of surface waters to the east of the Island and supports the chlorophyll analysis.

Whilst satellite telemetry gives a good insight into bloom dynamics in surface waters, results from the phytoplankton counts show that concentrations of *Pseudo-nitzschia* in bottom waters were on occasion higher than surface waters (see Figure 6).





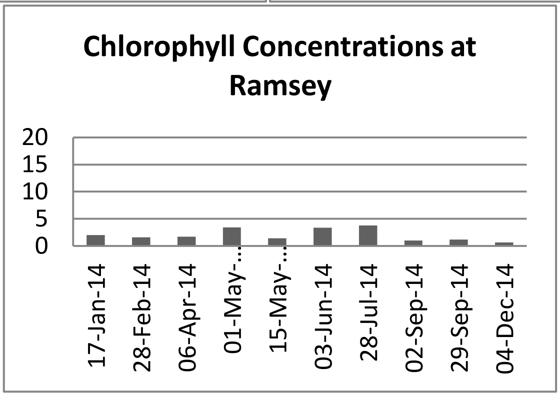


Figure 7. Chlorophyll concentrations (as µg/l) throughout the period of the phytoplankton bloom.

Bloom initiation was coincidental with a harbour dredging operation to remove sediments from Peel marina which was undertaken throughout April & May 2014. The dredged sediments were deposited at the licensed dumpsite to the west of Peel Bay. Analysis of the sediments showed them to be very high in leachable inorganic nutrients (Table 3) in particular ammonia (NH4) phosphate (PO4) and silicate (SiO2). It is highly possible that the addition of high concentrations of both ammonia and silicate helped stimulate and feed the diatom bloom at the time of discharge. Both *Pseudo-nitzschia* and *Chaetoceros* like all diatoms form silicate frustules, the high concentrations of leachable silicate and ammonia would have provided a suitable medium for growth and enabled populations to increase rapidly. This hypothesis is further supported by comparing east and west coast populations at this time, the east coast had much less phytoplankton biomass during this time and had no additional nutrient inputs via dredging operations.

Table 3. Comparison of leachable inorganic nutrients in dredged sediment and in coastal waters during April and May 2014 (all as µg/l).

	NO_2	NO_3	NH_4	PO_4	SiO_2
Peel sediment Leachate	0.46	2.27	50.46	1.86	46.23
West coast seawater Mean for April 2014	0.34	6.07	0.2	0.33	5.68
West coast seawater Mean for May 2014	0.07	0.43	0.6	0.11	0.6

The high concentrations of *Pseudo-nitzschia* cf. *seriata* prompted increase testing in the shellfish industry for domoic acid. Queen scallops were tested throughout the summer months and no increase in domoic acid was detected. Prior to the start of the King scallop season in 2014 analysis showed that DA concentrations in this species had indeed increased as a result of the *Pseudo-nitzschia* bloom in west coast fishing grounds (Figure 8). Concentrations of DA in September 2014 reached over 300 µg/g at these locations. Conversely king scallops fished from the east coast grounds had DA concentrations well below the legal limit of 20 µg/g. The DA intoxification in scallop beds along the west coast took over one year for concentrations to fall below minimum concentrations acceptable under European legislation.

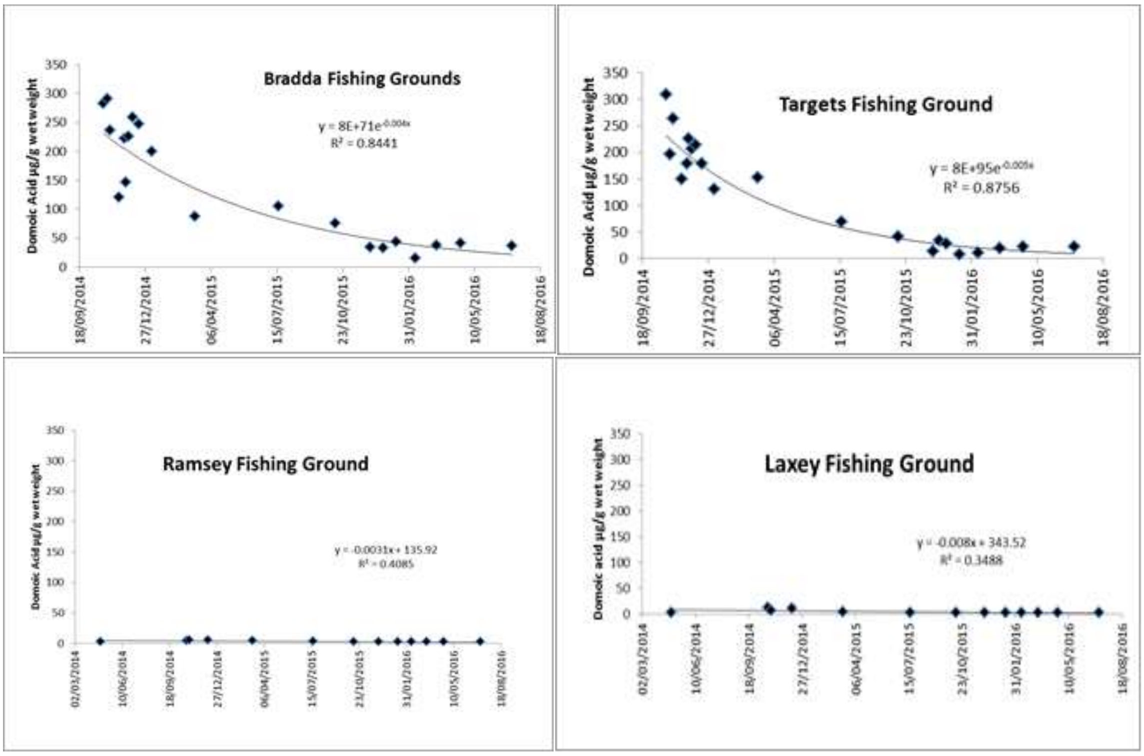


Figure 8. Domoic acid concentrations in King scallops September 2014 - September 2016.

Further analysis of different body parts of the king scallop showed that the majority of the phycotoxin was concentrated in the non-edible fraction of the animals (Figure 9). Concentrations in the adductor muscle remained low throughout the study. Domoic acid concentrations in the gonad (roe or coral) did exceed regulatory limits on one sampling occasion but were generally below maximum permissible limits set under European laws. As a consequence of the elevated levels of domoic acid, fisheries management measures such as ground closures and shucking restrictions were imposed to reduce the risk to consumers.

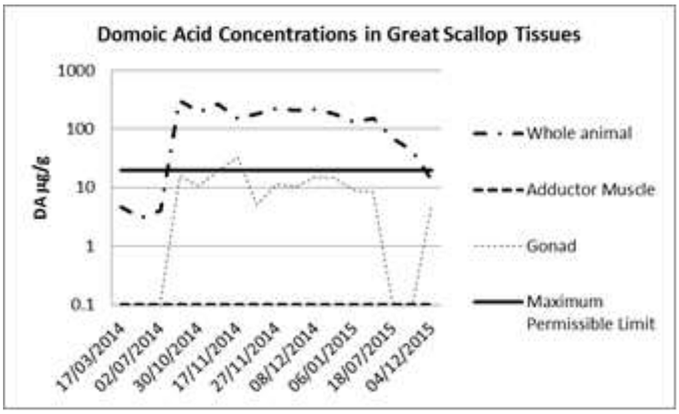


Figure 9. Concentrations of domoic acid in different body parts of king scallops.

The potential impact of toxic algal events in Manx waters is high. The Manx fishery is largely composed of a shellfish based fishery. The results of the 2014 *Pseudo-nitzschia* event highlight the need for monitoring and reporting of toxic algae in waters overlying shellfish grounds.

Monitoring programs around the Irish Sea are organised through national monitoring programs. Trigger levels for *Pseudo-nitzschia* species vary between these programs with Northern Ireland, England & Wales having a trigger of 150,000 cells/litre whist the Isle of Man, Scotland & Eire have a level set at 50,000 cells/litre. Results from the 2014 bloom in Manx waters would recommend a unified trigger level of 50,000 cells/litre as the maximum recorded concentrations throughout the study reached only 60,000 cells/litre and would have not triggered additional shellfish testing had the Northern Irish or English/Welsh levels been used.

Zooplankton

Relatively few studies on the zooplankton populations of Manx coastal waters have been undertaken. Two studies of note include a series of studies undertaken by Dr R. Nash in the late 1990s of waters to the west of the Island and also results obtained by the continuous plankton recorder (CPR) by the Sir Alistair Hardy Foundation for Ocean Science (SAHFOS). Results from both of these studies are summarised in Kennington and Rowlands (2006) to which the reader is referred.

From the observed zooplankton community in the western Irish Sea (Table 4) it is noted that copepods form the greatest proportion at nearly 70% of all the zooplankton. Of these copepods it is the smaller species of *Pseudocalanus elongates*, *Temora longicornis* and *Acartia clausii* that dominate. This population pattern is reflected in other areas of the Irish Sea such as the North Channel (Gowen *et al.* 1998) and the eastern Irish Sea (Graziano 1988). However, species composition does not generally differ between eastern and western regions. It is noted that a greater abundance of copepods is found in the western Irish Sea

(Graziano (1988).

Kennington and Rowlands (2006) review of plankton in the Irish Sea utilised data from the Sir Alistair Hardy Foundations' continuous plankton recorder over a forty-year period. Their study noted a significant decrease in zooplankton species abundance throughout this time interval in the Irish Sea.

Table 4. Composition of zooplankton in western Manx coastal waters with organisms >1% composition of their group (after Kennington & Rowlands (2006)).

Group	Species	% Composition of Group	% composition of all zooplankton	% composition of group in zooplankton
Copepods	*Pseudocalanus elongates*	38.8	26.28	69.01
	Temora longicornis	23.67	16.34	
	Acartia clausii	13.26	9.15	
	Calanus nauplii and copodites	7.07	4.88	
	Calanus helgolandicus	5.10	3.52	
	Centropages hamatus	3.29	2.27	
	Calanus finmarchicus	3.03	2.09	
	Paracalanus parvus	2.22	1.54	
	Oithona similis	1.37	0.94	
Other crustaceans	Decapoda	43.87	9.03	20.59
	Evadne normanii	22.90	4.72	
	Cirrepedia	13.99	2.88	
	Euphausiaceae	8.50	1.75	
	Podon intermedius	7.06	1.45	
	Isopoda	1.57	0.32	
	Podon leucarti	1.42	0.29	
Molluscs, echinoderms & Bryozoans	*Oikliopleura dioica*	35.10	1.89	5.39
	Echinoderm larvae	21.17	1.14	
	Gastropod larvae	19.55	1.05	
	Bryozoa	10.75	0.58	
	Fritillaria	7.24	0.39	
	Bivalvia	5.96	0.32	
Annelida	Polychaeta	64.82	1.99	3.07
	Tomopteridae	24.62	0.76	
	Syllidae	10.56	0.32	
Cnidarians, Chaetognaths & Ctenophores	Chaetognatha	68.51	1.33	1.94
	Hydromedusae	20.19	0.39	
	Ctenophora	6.42	0.12	
	Siphonophora	4.49	0.09	

Jellyfish

Jellyfish (Coelenterates) are probably the most conspicuous of the coastal plankton. Unlike zooplankton or phytoplankton, which are really only noticeable to most people when abundances reach such proportions that they result in a change in sea colour, the mega-planktonic jellyfish can often be observed more readily. Studies on jellyfish in the Irish Sea date back to Victorian times although it is only in the last decade or so that information on biomass and distributions have begun to be made. The most commonly reported species of jellyfish in the Irish Sea are *Aurelia aurita* (moon jellyfish), *Chrysaora hysoscella* (compass jellyfish) *Rhizostoma octopus* (Barrel jellyfish)*, Pelagia noctiluca* (mauve stinger), *Cyanea capillata* (Lion's-mane Jellyfish), and *Cyanea lamarckii* (blue or bluefire jellyfish).

An overview of gelatinous zooplankton in the Irish Sea is given in Kennington and Rowlands (2006) to which the reader is referred. More recent studies include the distribution and abundance data on two of the most common jellyfish species *Aurelia aurita* (moon jellyfish) and *Cyanea capillata* (lion's-mane jellyfish) which includes data collected from the Manx territorial sea (Bastien *et al.* 2010, Bastien 2011). These studies produced the first formal descriptions of the seasonal changes in the abundances and distributions of these two species in the Irish Sea. Bastien *et al.* (2011) were able to show that the peak abundances of these species tended to occur between June and September with highest overall abundances of *Cynanea capillata* occurring during mid-August.

Lynam *et al.* (2011) utilised data from fisheries surveys in the Irish Sea over the last two decades. This data included jellyfish caught in the surveys and was used to look at the abundance of jellyfish in the Irish Sea over a 16 year time period (Figure 10). Lynam et al. (2011) concluded that just as with other maritime areas, the Irish Sea had seen an increase in jellyfish abundance in recent years. This they attributed to several factors including fishing down of the food chain (e.g. the reduction of food competitors such as cod) and climate induced changes in the marine system.

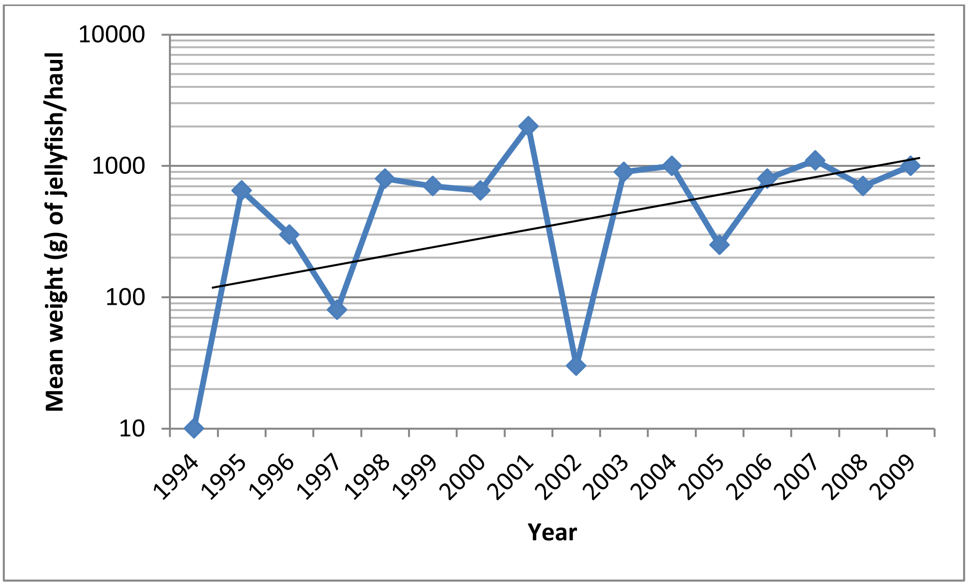


Figure 10. Temporal patterns of mean catch weights per haul of jellyfish in the western Irish Sea. (redrawn from Lynam et al. 2011)

Fish surveys undertaken by the Agriculture and Biosciences Institute of Northern Ireland record the number and weight of jellyfish species found in the fish trawls. These surveys, which are undertaken in June of each year, include several stations in Manx waters (Figure 11). Jellyfish abundance averaged across the stations show no underlying trend between 2007 and 2013 (Figure 12).

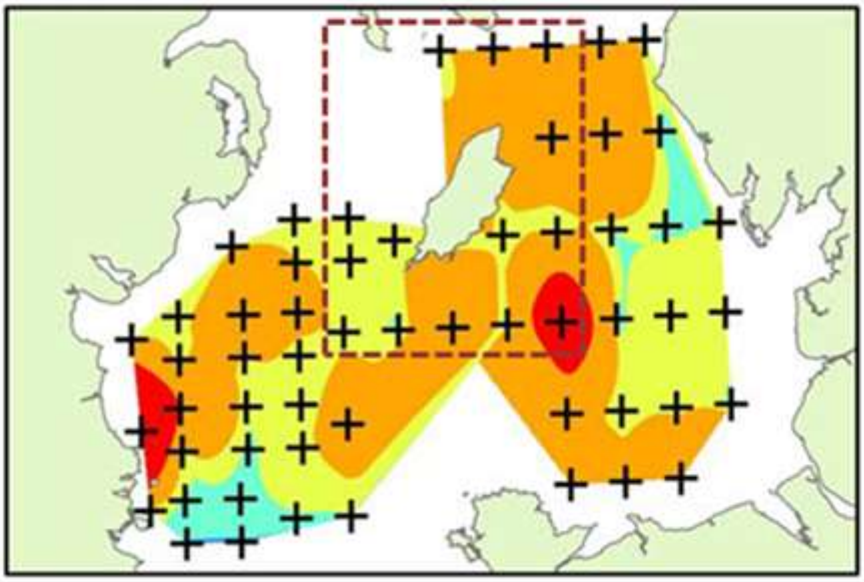


Figure 11. Location of the AFBI Irish Sea MIK net stations. Stations included in the Manx jellyfish biomass plot are delineated by the dotted red-box (Image courtesy of Dr. S. Beggs, AFBI).

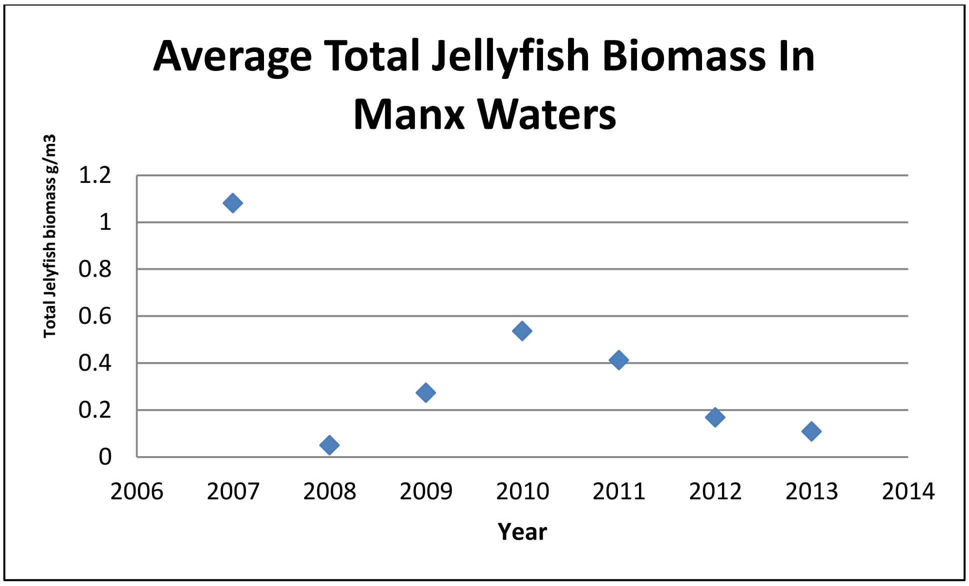


Figure 12. Average annual jellyfish biomass from data collected in Manx waters (data courtesy of Dr. S. Beggs, AFBI).

Summary and Recommendations

The long term monitoring programmes undertaken by the Isle of Man Government provides several services to society. By fulfilling the Island's obligations under the EEC directives mentioned earlier, regular monitoring ensures for example, that fish products brought to market are safe to eat. Additionally by keeping a regular check on the nutrient/phytoplankton dynamic which forms the basis of the marine food chain, the monitoring programmes can act as an early warning mechanism of change in the marine ecosystem. Such changes can be brought about through anthropogenic sources such as eutrophication which can alter ecosystem dynamics, impact upon fisheries and reduce society's enjoyment of the coastal zone. The programmes also form part of a broader network across the British Isles and beyond, providing information on large scale changes to the marine environment brought about through changing climates.

Any future developments undertaken in Manx territorial waters are unlikely to have substantial long-lasting effects upon either the nutrient regimes or the plankton community. However, localised, short term effects could be an issue. Any disruption of mobile sediments can release nutrients into the water column which may stimulate primary productivity in the local area. Additionally, certain noxious algal forms produce benthic resting stages (cysts, auxospores etc.) which can be very long lived in the sediments and can withstand burial to a considerable depth. The remobilisation of such cysts could, in theory at least, stimulate bloom formation of these algae. These impacts could be mitigated by careful selection of the time of year that these sediments are disturbed or by undertaking sediment-core analysis as part of an environmental impact assessment prior to development taking place.

The introduction of non-indigenous species of plankton has occurred in other water bodies around the globe via the discharge of ships ballast water. Any increase in shipping through Manx waters or increase in port activity has the potential to release these organisms into territorial waters. Such events have been proven to have had serious impacts on other European coastal waters and have been implicated with the spread of toxic algae which often have cysts which are long-lived (e.g. *Alexandrium* spp).

References

Allen J.R., Slinn D.J., Shammon T.M., Hartnoll R.G. and Hawkins S.J. (1998). Evidence for eutrophication in the Irish Sea over four decades. *Limnology and Oceanography* 43; 1970-1974.

Bastien T., Lilley M.K.S., Stokes D., Beggs S.E., Lynam C.P., Hays G.C., Davenport J. and Doyle T.K. (2010). How fish surveys provide a 'backbone' for jellyfish research. ICES CM 2010/R:06.

Bastien T., Haberlin D., Purcell J.E., Hays G.C., Davenport J., McAllen R. and Doyle T.K. (2011). Large-scale sampling reveals the spatio-temporal distributions of the jellyfish *Aurelia aurita* and *Cyanea capillata* in the Irish Sea. Marine Biology 158:2639–2652.

Bastien T. (2011). The broad-scale distribution and abundance of Scyphomedusae in Irish Waters. PhD thesis, NUI Cork. 154pp.

Bogan Y.M., Kennedy D.J., Harkin A.L., Gillespie J., Vause B.J., Beukers-Stewart, B.D., Hess P. and Slater J.W. 2007. 'Variation in domoic acid concentration in king scallop (Pecten maximus) from fishing grounds around the Isle of Man' Harmful algae, vol 6, no. 1, pp. 81-92. DOI: 10.1016/j.hal.2006.07.002

Davidson K., Miller P., Wilding T.A., Shutler J., Bresnan E., Kennington K. and Swan S. (2009). A large and prolonged bloom of *Karenia mikimotoi* in Scottish waters in 2006. *Harmful Algae* 8, 349-361.

Evans G.L., Williams P.J. and Le B. Mitchelson-Jacob E.G. (2003). Physical and anthropogenic effects on observed long term nutrient changes in the Irish Sea. *Estuarine, Coastal and Shelf Science* 57, 1159-1168.

Gilbert P.M., Anderson D.M., Gentian P., Graneli E. and Sellner K.G. (2005). The global complex phenomena of harmful algal blooms*. Oceanography* 18 (2) 136-147.

Gowen R.J., Hydes D.J., Mills D.K., Stewart B.M., Brown J., Gibson C.E., Shammon T.M., Allen M. and Malcolm S.J. (2002). Assessing trends in nutrient concentrations in coastal shelf seas: a case study in the Irish Sea. *Estuarine, Coastal and Shelf Science* 54, 927-939.

Gowen R.J., Tett P., Kennington K., Mills D.K., Shammon T.M., Stewart B.M., Greenwood N., Flanagan C., Devlin M. and Wither A. (2008). The Irish Sea: Is it eutrophic? *Estuarine, Coastal and Shelf Science* 76, 239-254.

Gowen R.J., McQuatters-Gollop A., Tett P., Best M., Bresnan E., Castellani C., Cook K., Forster R., Scherer C. and Mckinney A. (2011). The Development of UK Pelagic (Plankton) Indicators and Targets for the MSFD. A Report of a workshop held at AFBI, Belfast 2-3rd June 2011. 41pp.

Gowen R.J. and Stewart B.M. (2005). The Irish Sea: nutrient status and phytoplankton. *Journal of Sea Research* 54, 36-50.

Graziano C. (1988). Some observations on the plankton of the north Irish Sea. PhD Thesis, Liverpool University. pp: 121.

Kennington K., Allen J.R., Shammon T.M., Jones P. and Hartnoll R.G. (1999). Phytoplankton and nutrient dynamics in the north-east Irish Sea. *Hydrobiologia* 393: 57-67.

Kennington K., Wither A., Shammon T.M., Jones P., Harrison A., Kraberg A. and Hartnoll R.G. (2004). The distribution of nutrient and phytoplankton in the eastern Irish Sea during 2002. U.K. Environment Agency Technical Report E-1049/TR6.

Kennington K. and Rowlands W.L. (2006). SEA Area 6 Technical report – Plankton ecology of the Irish Sea. Report to the Department of Trade and Industry of the UK. 62pp.

Lynam C.P., Lilley M. K. S., Bastian T., Doyle T. K., Beggs S. E. and Hays G.C. (2011). Have jellyfish in the Irish Sea benefited from climate change and over fishing? *Global Change Biology* 17: 767–782.

Montagnes D.J.S., Poulton A.J. and Shammon T.M. (1999). Mesoscale, finescale and microscale distribution of micro- and nanoplankton in the Irish Sea, with emphasis on ciliates and their prey. *Marine Biology* 134: 167-179.

Shammon T.M., Kennington K. and Hartnoll R.G. (2004). Long term studies in the Irish Sea: Environmental monitoring and contamination. 12th Report to the Department of Local Government and the Environment, IOM Government. 68pp.