Appendix 14A

(web version)

Pigments and toxins of harmful algae

(including algae for which pigment information was not found)

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As there is an increasing requirement to monitor harmful algal blooms (HABs), it is useful to have knowledge on both the pigments and toxins associated with these blooms. Table 14A.1 presents a compilation of photosynthetic or mixotrophic phytoplankton species known to cause HABs in marine, brackish or fresh water with detailed information on their specific toxins and pigments. Heterotrophic dinoflagellates, some of which are known to produce harmful blooms, have been excluded from the list because they do not contain photosynthetic pigments and this volume focuses on algal pigments. Also excluded are species of algae found to be harmful or toxic only under laboratory conditions, since these species are either not bloom forming or they do not cause harm as a bloom.

The literature associated with this topic is extensive and about 2500 articles were collected for this survey. Due to the large number of references, a few articles

may have slipped through the author's notice, or may have been unavailable through the library searching and ordering system. Also, as the literature survey was performed in early 2008, more recent articles may not all be listed.

A shorter version of this Table can be found in the print version of this book, with only the HAB species for which pigment information was reported. It is interesting to note that pigment information is missing for a large number of HAB species.

Table 14A.1. List of phytoplankton species known to produce harmful algal blooms, their major toxins and harmful effects, and their chlorophyll and carotenoid pigments as reported in the selected references shown in the last column. Also shown are other compounds potentially useful for detection purposes, such as mycosporine-like amino acids (MAAs – for details on these, see Table 10.2 in Chapter 10, this volume). For pigment abbreviations, see the list of abbreviations at the beginning of this volume. Pigments and other compounds are listed as found in the references; others may be present, but only those reported in the references are listed (e.g. Chl *a* should be present in all of the species listed below). Toxic syndromes abbreviations are as found in Chapter 14. In the last column, 'IOC' refers to the IOC list of harmful algae; see Moestrup *et al*. (2009).

Algal species	**Synonym(s)**	**Algal class**	**Toxin**	**Harmful effect**	**Chlorophyll**	**Carotenoid**	**Other pigment**	**Selected references**
Akashiwo sanguinea	*Gymnodinium nelsonii, G. sanguineum, G. splendens*	Dinophyceae		oxygen depletion, abalone and oyster larvae mortality		ββ-Car, Diadino, Diato, Dino, Peri, peridinol	MAAs	Botes *et al.* (2003a), Johansen *et al*. (1974), Matsubara *et al.* (2007)
Alexandrium acatenella	*Gessnerium acatenellum, Gonyaulax acatenella, Protogonyaulax acatenella*	Dinophyceae		PSP				IOC, Prakash and Taylor (1966)
Alexandrium affine	*Alexandrium fukuyoi, Protogonyaulax affinis*	Dinophyceae	gonyautoxins 1–4, neosaxitoxin, saxitoxin	non-toxic or low toxicity, PSP				Nguyen-Ngoc (2004), Wang *et al.* (2006)
Alexandrium andersonii	*Alexandrium andersoni*	Dinophyceae	gonyautoxins 1–4, neosaxitoxin, saxitoxin	non-toxic or toxic, PSP				IOC, Balech (1990), Ciminiello *et al.* (2000), Frangópulos *et al.* (2004), Lilly *et al.* (2005)
Alexandrium balechii	*Gessnerium balechii, Gonyaulax balechii, Pyrodinium balechii*	Dinophyceae		oxygen depletion, fish mortality				IOC, Steidinger (1971)
Alexandrium catenella	*Gessnerium catenellum, Gonyaulax*	Dinophyceae	decarbamoylgonyau toxins 2–3,	fish mortality, PSP	Chl *a*, Chl c_2,	ββ-Car, Diadino,	MAAs	IOC, Boczar *et al.* (1988), Carreto *et*

	catenella, G. tamarensis var. *excavata, Protogonyaulax catenella*		decarbamoylsaxitoxin, gonyautoxins 1–6, neosaxitoxin, *N*-sulfocarbamoylgonyautoxins 1–4 (C1–C4)		MgDVP	Diato, Dino, Peri, peridininol		*al.* (2001), Hallegraeff *et al.* (1991a), Kaga *et al.* (2006), Kim *et al.* (2005), Matsuda *et al.* (2006), Navarro *et al.* (2006)
Alexandrium fundyense	*Gonyaulax excavata* (also included in *Alexandrium tamarense*)	Dinophyceae	decarbamoylgonyautoxins 3, gonyautoxins 1–5, neosaxitoxin, saxitoxin, *N*-sulfocarbamoylgonyautoxins 2–3 (C1–C2)	PSP				IOC, Poulton *et al.* (2005)
Alexandrium hiranoi	*Alexandrium pseudogoniaulax, Gomiodoma pseudogoniaulax*	Dinophyceae	goniodomin A	antifungal, toxic to mice				IOC, Murakami *et al.* (1998), Terao *et al.* (1989)
Alexandrium leei		Dinophyceae	gonyautoxins 1–4, ichthyotoxin(s), neosaxitoxin, saxitoxin	non-toxic or toxic, fish mortality, PSP				Nguyen-Ngoc (2004), Tang *et al.* (2007)
Alexandrium minutum	*Alexandrium angustitabulatum, A. ibericum, A. lusitanicum, Pyrodinium minutum*	Dinophyceae	decarbamoylsaxitoxin, deoxygonyautoxin 4-12-ol, gonyautoxins 1–4, neosaxitoxin, saxitoxin	PSP	Chl *a*, Chl c_2, Chl c_3, MgDVP	ββ-Car, Diadino, Diato, Dino, Peri, peridininol	MAAs	IOC, Carreto *et al.* (2001), Chen and Chou (2001), Lim *et al.* (2007), Nascimento *et al.* (2005a)
Alexandrium monilatum	*Gessnerium mochimaensis, Gessnerium monilata, Gonaulax monilata (-*	Dinophyceae	goniodomin A	fish mortality, haemolysis				IOC, Hsia *et al.* (2006)

	tum), Pyrodinium monilatum							
Alexandrium ostenfeldii	*Gessnerium ostenfeldii, Goniodoma ostenfeldii, Gonyaulax globosa, G. ostenfeldii, G. tamarensis* var. *globosa, G. trygvei, Heteraulacus ostenfeldii, Protogonyaulax globosa, P. ostenfeldii, Pyrodinium phoneus, Triadinium ostenfeldii*	Dinophyceae	gonyautoxins 2–6, neosaxitoxin, saxitoxin, spirolide A, spirolide B, spirolide C, spirolide 13-desmethyl C, spirolidine 13,19-didesmetyl C, spirolide D, spirolide D2, spirolide D3, spirolide 13-desmethyl D, spirolidine G	neurotoxins, PSP				IOC, Cembella *et al.* (1999), Ciminiello *et al.* (2006b), Hansen *et al.* (1992), MacKinnon *et al.* (2006), Ravn *et al.* (1995)
Alexandrium peruvianum	*Gonyaulax peruviana*	Dinophyceae	decarbamoylsaxitoxin, gonyaulaxtoxins 1, 4–6, saxitoxin	weakly toxic, PSP				Lim *et al.* (2005), Lim and Ogata (2005)
Alexandrium tamarense	*Alexandrium excavatum, Gessnerium tamarensis, Gonyaulax excavata, G. tamarensis, G. tamarensis* var. *excavata, Protogonyaulax tamarensis*	Dinophyceae	decarbamoylgonyautoxins 2–3, decarbamoylsaxitoxin, gonyaulaxtoxins 1–6, neosaxitoxin, saxitoxin, *N*-sulfocarbamoylgonyautoxins 1–4 (C1–C4)	non-toxic or toxic, PSP	Chl *a*, Chl c_2, MgDVP	ββ-Car, Diadino, Diato, Dino, Peri, peridininol	MAAs	IOC, Carreto *et al.* (2001), Collins *et al.* (2009), Hallegraeff *et al.* (1991a), Kaga *et al.* (2006), Kim *et al.* (2005), Laurion and Roy (2009)
Alexandrium tamiyavanichii	*Alexandrium cohorticula, Gessnerium cohorticula, Gonyaulax cohorticula, Protogonyaulax*	Dinophyceae	decarbamoylsaxitoxin, saxitoxin, *N*-sulfocarbamoylgonyautoxins 1–4 (C1–C4)	PSP	Chl *a*	Peri		IOC, Kodama *et al.* (1988), Lim *et al.* (2006), Ogata *et al.* (1990), Ogata *et al.* (1994)

	cohorticula							
Alexandrium taylorii	*Alexandrium taylori*	Dinophyceae	decarbamoylsaxitoxin, gonyautoxins 2–6, neosaxitoxin	haemolysis	Chl *a*			Emura *et al.* (2004), Lim *et al.* (2005)
Amphidinium carterae		Dinophyceae	amphidinols 2, 4, 9–13, haemolysins 1–5	fish toxicity, haemolysis	Chl *a*, Chl c_2	ββ-Car, Diadino, Diato, Dino, P457, Peri, peridininol	MAAs	IOC, Echigoya *et al.* (2005), Hannach and Sigleo (1998), Jeffrey and Wright (1997), Johansen *et al.* (1974), Nayak *et al.* (1997)
Amphidinium gibbosum	*Amphidinium operculatum* var. *gibbosum*	Dinophyceae	amphidinoketides I–II, amphidinolides B1–B3, caribenolide 1	antitumor activity, cytotoxic				IOC, Bauer *et al.* (1994), Bauer *et al.* (1995a), Bauer *et al.* (1995b)
Amphidinium operculatum	*Amphidinium klebsii*	Dinophyceae	amphidinols 1–8, 14–15	antifungal activity, haemolysis, fish mortality?	Chl *a*, Chl *c*	carotene(s), Diadino, Dino, Peri		IOC, Echigoya *et al.* (2005), Mandelli (1969), Morsy *et al.* (2005), Morsy *et al.* (2006), Wilhelm and Manns (1991)
Amphora coffeaeformis	*Amphora coffaeiformis, Frustulia coffeaeformis*	Bacillariophyceae	domoic acid (identity of toxic strain not proved)	non-toxic or toxic, DA	Chl *a*, Chl *c*	Diadino, Diato, Fuco		IOC, Rech *et al.* (2005), Sala *et al.* (1998), Shimizu *et al.* (1989)
Anabaena bergii		Nostocophyceae	cylindrospermopsin					Schembri *et al.* (2001)
Anabaena circinalis	*Anabaena hassalii*	Nostocophyceae	decarbamoylgonyautoxins 2–3, decarbamoylsaxitoxin, gony-autoxins 2–	non-toxic or toxic, PSP	Chl *a*		c-phyco-cyanin	Millie *et al.* (1992), Negri *et al.* (1997)

			3, 5, saxitoxin, *N*-sulfo-carbamoylgonyautoxins 2–3 (C1–C2)					
Anabaena flos-aquae		Nostocophyceae	anabaenopeptins A–B, anatoxins a–d, anatoxin-a(s), micro-cystin-LR, [D-Asp^3] microcystin-LR, [D-Asp^3,D-Glu(OCH$_3$)$_6$] microcystin-LR, [D-Glu(OCH$_3$)$_6$]microcystin-LR, micro-cystin-RR, [D-Asp^3] microcystin-RR	hepatotoxic	Chl *a*	Cantha, ββ-Car, Echin, Kmyxo, Myxo		Carmichael and Gorham (1978), Harada *et al.* (1995), Hertzberg *et al.* (1971), Leavitt and Brown (1988), Onodera *et al.* (1997a), Sivonen *et al.* (1992)
Anabaena lemmermannii		Nostocophyceae	anatoxin-a(s)	neurotoxic		aphanizophyll, Cantha, ββ-Car, Cryp, Echin, Myxo, Oscil, Zea		Onodera *et al.* (1997a), Schlüter *et al.* (2004)
Anabaena macrospora		Nostocophyceae	anatoxin-a, anatoxin-a epoxide					Park *et al.* (1993)
Anabaena mendotae	*Dolicospermum mendotae*	Nostocophyceae	anatoxin-a	neurotoxic				Rapala *et al.* (1993)
Anabaena perubata f. *tumida*		Nostocophyceae	gonyautoxin 2 and/or 3	PSP				Velzeboer *et al.* (2000)
Anabaena planctonica		Nostocophyceae	anatoxin-a, anatoxin-a epoxide					Park *et al.* (1993)
Anabaena spiroides		Nostocophyceae	anatoxin-a, anatoxin-a epoxide, gonyautoxin 2	inhibits cyanobacterial growth, PSP				Kaya *et al.* (2002), Park *et al.* (1993), Velzeboer *et al.*

			and/or 3, spiroidesin					(2000)
Anabaena variabilis		Nostocophyceae	anatoxin			Cantha, ββ-Car, Echin, Myxo, Zea		Hertzberg *et al.* (1971)
Anabaenopsis milleri		Nostocophyceae	anatoxin, microcystin-LR (?)	hepatotoxic				Lanaras and Cook (1994)
Aphanizomenon flos-aquae	*Aphanizomenon* DC-1	Nostocophyceae	anatoxin-a, cylindrospermopsin, decarbamoylgonyautoxin 3, decarbamoylsaxitoxin, gonyautoxins 1, 3–5, neosaxitoxin, saxitoxin	non-toxic or toxic, hepatotoxic, neurotoxic, PSP, tadpole mass mortality	Chl *a*	aphanizophyll, Cantha, ββ-Car, β,β-carotene epoxide, Echin, Myxo		Ferreira *et al.* (2001), Hertzberg and Liaaen-Jensen (1966b), Liu *et al.* (2006a), Liu *et al.* (2006b), Preußel *et al.* (2006), Rapala *et al.* (1993)
Aphanizomenon gracile	*Anabaena flos-aquae* var. *gracile*, *Aphanizomenon flos-aquae* cf. *gracile*	Nostocophyceae	cylindrosperopsin, neosaxitoxin, saxitoxin	hepatotoxic, PSP				Pereira *et al.* (2004), Rücker *et al.* (2007)
Aphanizomenon issatschenkoi	*'Aphanizomenon flos-aquae'* LMECYA 31	Nostocophyceae	anatoxin-a, 11-carboxylanatoxin-a, decarbamoylsaxitoxin, gonyautoxins 5–6, neosaxitoxin, saxitoxin	PSP				Pereira *et al.* (2000), Selwood *et al.* (2007)
Aphanizomenon ovalisporum		Nostocophyceae	cylindrospermopsin	non-toxic or toxic, hepatotoxic				Banker *et al.* (1997)
Arthrospira fusiformis	*Spirulina fus(s)iformis*, *S. platensis*	Nostocophyceae	anatoxin-a, microcystin YR	non-toxic or toxic		ββ-Car, β,β-carotene-5,6-epoxide, Cryp, Echin, 3'-hydroxyechinenone,	c-phycocyanin, phycoerythrin	Aakermann *et al.* (1992), Ballot *et al.* (2004), Madhyastha and Vatsala (2007)

						Myxo, Oscil, Zea		
Aureococcus anophagefferens		Pelagophyceae		shellfish mass mortality	Chl *a*, Chl *c* Chl c_3	But-fuco, ββ-Car, Diadino, Diato, Fuco		Bidigare (1989), DeYoe *et al.* (1997), Hargraves and Maranda (2002)
Botryococcus braunii		Chlorophyceae	linoleic acid, α-linolenic acid, oleic acid	fish mortality	Chl *a*, Chl *b*	adonixanthin, Asta, botryoxanthins A–B, α-botryoxanthin A, braunixanthins 1–2, Cantha, ββ-Car, βε-Car, Echin, 3-hydroxyechinenone, 3'-hydroxyechinenone, Loro, Lut, Neo, Viola, Zea		Chiang *et al.* (2004), Grung *et al.* (1994a, b), Okada (1999)
Ceratium furca	*Peridinium furca*	Dinophyceae		oxygen depletion causing fish mortality				Glibert *et al.* (2002), Lu and Hodgkiss (2004)
Chaetoceros concavicornis		Bacillariophyceae		gill damage causing fish mortality				Albright *et al.* (1993), Horner *et al.* (1997), Yang and Albright (1992)
Chaetoceros		Bacillarioph		gill damage				Albright *et al.*

convolutus		yceae		causing crab and fish mortality				(1993), Bell (1961), Horner *et al.* (1997), Tester and Mahoney (1995)
*Chattonella antiqua**	*Hemieutreptia antiqua*	Raphidophyceae	brevetoxins PbTx-1–3, oxidized PbTx-2	fish mortality, neurotoxic	Chl *a*	Fuco, Viola		IOC, Haque and Onoue (2002), Kohata *et al.* (1997)
Chattonella globosa		Raphidophyceae		gill damage causing fish mortality				IOC, Hara *et al.* (1994)
*Chattonella marina**	*Hornellia marina*	Raphidophyceae	brevetoxins PbTx-2–3, 9, oxidized PbTx-2 (CmTx), free fatty acids, reactive oxygen (disputed harmful effect), unidentified cytotoxin	cytotoxic, gill damage, neurotoxic				IOC, Haque and Onoue (2002), Kuroda *et al.* (2005), Marshall *et al.* (2002), Tang *et al.* (2005)
*Chattonella ovata**		Raphidophyceae	reactive oxygen	fish mortality				Hiroshi *et al.* (2005)
Chattonella subsalsa		Raphidophyceae		fish mortality				IOC, Biecheler (1936)
Chrysochromulina leadbeateri		Prymnesiophyceae		fish mortality, haemolysis, osmotic stress in fish	Chl *a*, Chl c_2, Chl c_3, MGDG, MgDVP, MV-Chl c_3	ββ-Car, Diadino, Diato, Fuco, Hex-fuco		IOC, Johnsen *et al.* (1999), Rodríguez *et al.* (2006), Simonsen and Moestrup (1997), Zapata *et al.* (2001)
Chrysochromulina polylepis		Prymnesiophyceae	haemolysins	animal, bacterial and fish mortality, haemolysis, osmotic stress in	Chl *a*, Chl c_2, Chl c_3, MGDG	ββ-Car, Diadino, Diato, Fuco, Hex-		IOC, Johnsen *et al.* (1992), Yasumoto *et al.* (1990), Zapata *et al.*

				fish		fuco, Hex-kfuco		(2004)
Cochlodinium catenatum		Dinophyceae		fish mortality				Ovalle *et al.* (2007)
Cochlodinium polykrikoides	*Cochlodinium heterolobatum*	Dinophyceae	reactive oxygen (disputed)	fish mortality				IOC, Kim *et al.* (2002)
Coelosphaerium kuetzingianum		Nostocophyceae		animal and bird mass mortality				Fitch *et al.* (1934)
Coolia monotis	*Glenodinium monotis*	Dinophyceae	cooliatoxin	non-toxic or toxic, *Artemia* and *Haliotis* larvae mortality, mice mortality				IOC, Rhodes *et al.* (2000b)
Cyanobium bacillare	*Synechococcus bacillare*	Nostocophyceae	microcystins	bird mass mortality				Cronberg *et al.* (2004)
Cylindrospermopsis raciborskii		Nostocophyceae	cylindrospermopsin, decarbamoylneosaxitoxin, decarbamoylsaxitoxin, deoxy-cylindrospermopsin, gonyautoxins 2–3, 6, neosaxitoxin, saxitoxin, *N*-sulfocarba-moylgonyautoxins 2–3 (C1–C2)	non-toxic or toxic, cattle mortality, hepatotoxic, PSP	Chl *a*	ββ-Car, Echin, Myxo, Zea		Bernard *et al.* (2003), Falconer and Humpage (2006), Lagos *et al.* (1999), Molica *et al.* (2002), Norris *et al.* (1999), Pomati *et al.* (2004), Thomas *et al.* (1998), Várkonyi *et al.* (2002)
Dictyocha speculum	*Distephanus speculum*	Dictyochophyceae	oxygen depletion	fish mortality	Chl *a*, Chl *c* (c_1 or c_2), Chl c_3	But-fuco, ββ-Car, Diadino, Diato, Fuco, Hex-fuco, Viola, Zea		Daugbjerg and Henriksen (2001), Henriksen *et al.* (1993)
Dinophysis	*Dinophysis boehmii, D.*	Dinophyceae	dinophysistoxin 1,	DSP			phycoer	IOC, Blanco *et al.*

acuminata	*borealis, D. lachmanni*		okadaic acid, pectenotoxin 2, 2-SA, 11, 11-SA?, 12				ythrin	(2007), Hewes *et al.* (1998), MacKenzie *et al.* (2005), Miles *et al.* (2004)
Dinophysis acuta		Dinophyceae	dinophysistoxin 1–2, 7-epipectenotoxin 2-SA, okadaic acid, okadaic acid esters, pectenotoxin 2, 2-SA, 2-SAi, 11, 11-SA, 12	DSP				IOC, Fernández *et al.* (2006), MacKenzie *et al.* (2005), Miles *et al.* (2004), Puente *et al.* (2004), Suzuki *et al.* (2003)
Dinophysis caudata	*Dinophysis diegensis*	Dinophyceae	dinophysistoxin 1, okadaic acid, pectenotoxin 2	DSP			phycoer ythrin	IOC, Fernández *et al.* (2006), Hewes *et al.* (1998), Marasigan *et al.* (2001)
Dinophysis fortii	*Dinophysis intermedia, Dinophysis laevis, D. ovum*	Dinophyceae	dinophysistoxin 1, okadaic acid, pectenotoxin 2	DSP			phycoer ythrin	IOC, Draisci *et al.* (1996), Hewes *et al.* (1998)
Dinophysis miles		Dinophyceae	dinophysistoxin 1, okadaic acid	DSP				IOC, Marasigan *et al.* (2001)
Dinophysis norvegica		Dinophyceae	dinophysistoxin 1, okadaic acid, pectenotoxin 2, 12	DSP	Chl *a*, Chl c_2	Allo	phycoer ythrin	IOC, Geider and Gunter (1989), Meyer-Harms and Pollehne (1998), Miles *et al.* (2004)
Dinophysis sacculus	*Dinophysis acuminata* cf. *reniformis, D. pavillardii, D. reniformis, D. ventrectra*	Dinophyceae	dinophysistoxin 1, okadaic acid	DSP				IOC, Giacobbe *et al.* (2000)
Dinophysis tripos	*Dinophysis taylorii, D. caudata* var. *tripos*	Dinophyceae	dinophysistoxin 1	DSP				IOC, Lee *et al.* (1989)
Eucampia zodiacus		Bacillarioph		discoloration of				Nishikawa and

		yceae		*Porphyra* thalli				Hori (2004)
Fibrocapsa japonica	*Chattonella japonica*	Raphidophyceae	brevetoxins PbTx-1–3, 9, oxidized PbTx-2 (CmTx)	fish mortality				IOC, Khan *et al.* (1996)
*Gambierdiscus toxicus***		Dinophyceae	ciguatoxins 3C, 4A, 4B, gambieric acids A–D, gambierol, maitotoxin 1–3	antifungal activity, fish mortality, neurotoxic (ciguatera)	Chl *a*, Chl *c*	ββ-Car, Diadino, Dino, Peri		IOC, Diogène *et al.* (1994), Indelicato and Watson (1986), Morohashi *et al.* (1998), Morohashi *et al.* (2000)
Gloeotrichia echinulata	*Conferva echinulata, Echinella articulata, Gloeotrichia pisum, Micrasterias articulata, Rivularia fluitans*	Nostocophyceae		animal (mass) mortality				Fitch *et al.* (1934)
Gonyaulax spinifera	included in *Gonyaulax baltica*?, *Peridinium spiniferum*	Dinophyceae	yessotoxin	shellfish toxic				Rhodes *et al.* (2006)
Gymnodinium catenatum		Dinophyceae	decarbamoylgonyautoxin 2–3, decarbamoylsaxitoxin, deoxysaxitoxin, GC 1–3, gonyautoxins 2–6 (GTX 5–6 = B1–2), neosaxitoxin, saxitoxin, *N*-sulfocarbamoylgonyautoxin 1–4 (C1–C4)	PSP	Chl *a*, Chl c_2	ββ-Car, Diadino, Diato, Dino, Peri	MAAs	IOC, Band-Schmidt *et al.* (2006), Hallegraeff *et al.* (1991b), Jeffrey *et al.* (1999), Montoya *et al.* (2006), Negri *et al.* (2003), Ordás *et al.* (2004), Oshima *et al.* (1993)
Gyrodinium corsicum		Dinophyceae		*Artemia* and fish mortality, haemolysis?, neurotoxic				da Costa *et al.* (2005a), da Costa *et al.* (2005b)

				shellfish poisoning-like				
Gyrodinium impudicum	*Gymnodinium impudicum*	Dinophyceae	sulphated exopolysaccharide	antiviral and immunostimulant activity	Chl *a*, Chl c_2	ββ-Car, Diadino, Diato, Dino, Peri, peridininol		Fraga *et al.* (1995), Yim *et al.* (2003), Yim *et al.* (2005)
Gyrodinium instriatum		Dinophyceae		feeds on ciliates, shrimp mortality				Uchida *et al.* (1997)
Heterocapsa circularisquama		Dinophyceae	H2-a, H3-a, photosensitizing toxins	haemolysis				IOC, Miyazaki *et al.* (2005)
Heterosigma akashiwo	*Entomosigma akashiwo*, *Heterosigma carterae*, *Olisthodiscus carterae*, *Olisthodiscus luteus*	Raphidophyceae	brevetoxins PbTx-2–3, 9, oxidized PbTx-2	fish mortality	Chl *a*, Chl c_1, Chl c_2	Anth, ββ-Car, Fuco, Hex-fuco, Viola, Zea		IOC, Li *et al.* (2003), Rodríguez *et al.* (2006)
Hormothamnion entromorphoides		Nostocophyceae	hormothamnin A and related compounds, laxaphycin A and related compounds, hormothamnione	antifungal and antigrazing effect, cytotoxic			hormothamnione	Gerwick *et al.* (1986), Gerwick *et al.* (1989), Pennings *et al.* (1997)
Karenia brevis	*Gymnodinium breve*, *Gymnodinium brevis*, *Ptychodiscus brevis*	Dinophyceae	brevetoxins PbTx-1–3, 5–7, 9–12, 927, tbm, hemibrevetoxin-B, hydrolytic PbTx-1–3, 7, hydrolytic oxidized PbTx-1–2, oxidized PbTx-1–2	fish and invertebrate mortality, NSP	Chl *a*, Chl *c*, Chl c_3	But-fuco, ββ-Car, βε-Car, Diadino, Diato, Fuco, Gyro-e, Hex-fuco, Hex-kfuco	MAAs	IOC, Abraham *et al.* (2006), Baden *et al.* (2005), Bidigare et al. 1990, Bjørnland *et al.* (2003), Frame (2004), Hernández-Becerril *et al.* (2007), Prasad and Shimizu (1989), Twiner *et al.*

								(2007)
Karenia brevisulcata	*Gymnodinium brevisulcatum*	Dinophyceae	KBTs (*Karenia brevisulcata* toxins) and BSXs (brevisulcatic acids)	algal, fish and invertebrate mortality, human respiratory distress				IOC, Chang *et al.* (2001), Shi *et al*. (in press)
Karenia concordia		Dinophyceae		fish mortality				IOC, Chang and Ryan (2004)
Karenia cristata		Dinophyceae		human respiratory and skin distress, invertebrate mortality	Chl *a*, Chl c_2, Chl c_3	But-fuco, ββ-Car, Diadino, Fuco, Gyro-e, Hex-fuco		IOC, Botes *et al.* (2003b)
Karenia digitata		Dinophyceae		fish mortality				IOC, Yang *et al.* (2000)
Karenia mikimotoi	*Gymnodinium mikimotoi, Gymnodinium nagasakiense* (often confused with *Gymnodinium aureolum* = *Gyrodinium aureolum)*	Dinophyceae	gymnocin A, B, reactive oxygen	fish and invertebrate mortality	Chl *a*, Chl $c_{1/2}$, Chl c_3	But-fuco, ββ-Car, βε-Car, Diadino, Fuco, Gyro-e, Hex-fuco		IOC, Hansen *et al.* (2000), Johnsen and Sakshaug (1993), Satake *et al.* (2005), Tsukano and Sasaki (2006), Yamasaki *et al.* (2004)
Karenia selliformis	*Gymnodinium* sp. '*selliformis*'	Dinophyceae	gymnodimine, gymnodimine B, C	fish mortality, NSP				IOC, Haywood *et al.* (2004), Heil *et al.* (2001), Miles *et al.* (2003), Mountfort *et al.* (2006)
Karenia umbella		Dinophyceae		fish mortality	Chl *a*, Chl c_2, Chl c_3	Diadino, Diato, Fuco, Gyro-e, Hex-fuco,		IOC, de Salas *et al.* (2004)

						Hex-kfuco, Zea		
Karlodinium armiger		Dinophyceae		fish and invertebrate mortality	Chl *a*, Chl c_2, Chl c_3, MGDG	But-fuco, ββ-Car, βε-Car, Diadino, Diato, Fuco, Gyro-e, Hex-fuco		IOC, Bergholtz *et al.* (2005), Garcés *et al.* (2006)
Karlodinium veneficum	*Gymnodinium galatheanum, Gymnodinium veneficum, Gyrodinium galatheanum, Karlodinium micrum, Woloszynskia micra*	Dinophyceae	karlotoxins 1–2,	fish and invertebrate mortality	Chl *a*, Chl c_2, Chl c_3, MgDVP	But-fuco, ββ-Car, Diadino, Diato, Fuco, Gyro-e, Hex-fuco, Viola, Zea		IOC, Adolf *et al.* (2006), Bachvaroff *et al.* (2009), Bergholtz *et al.* (2005), Bjørnland *et al.* (2003), Deeds *et al.* (2006), Johnsen and Sakshaug (1993), Kempton *et al.* (2002), Mooney *et al.* (2009)
Lingulodinium polyedrum	*Gonyaulax polyedra*	Dinophyceae	various yessotoxins and derivatives	toxic to shellfish	Chl *a*, Chl *c*	Peri	MAAs	Bowden (2006), Paz *et al.* (2004), Prézelin and Haxo (1976), Whitehead and Vernet (2000)
Limnothrix redekei	*Oscillatoria redekei*	Nostocophyceae	α-dimorphecolic acid, coriolic acid, microcystins (?)	antibacterial activity, immunosuppressant	Chl *a*	ββ-Car, Echin, Oscil, Zea		Effmert *et al.* (1991), Mundt *et al.* (2003), Nicklisch and Woitke (1999)
Lyngbya majuscula	*Microcoleus lyngbyaceus*	Nostocophyceae	aurilides B–C, antillatoxin,	antifungal and antimicrobial				Arthur *et al.* (2006), Bagchi

			antillatoxin B, curacin A–C, debromoaplysiatoxin, kalkitoxin, laxaphycins A–B, lyngbyatoxin A, malynamide A–B, G, etc.	effects, antitumor activity, benign tumors in marine turtles, fish mortality, human eye and skin distress, neurotoxic				(1996), Bonnard *et al.* (1997), Han *et al.* (2006), Nagle and Paul (1999), Nogle *et al.* (2001), Osborne *et al.* (2001), Osborne *et al.* (2007), Pennings *et al.* (1996), Shimizu (2003), Wu *et al.* (2000)
Lyngbya wollei	*Lyngbya latissima, Lyngbya magnifica, Plectonema wollei, Plectonema wollei* f. *robustum (-ta)*	Nostocophyceae	cylindrospermopsin, decarbamoylgonyautoxins 2–3, decarbamoylsaxitoxin, deoxycylindrospermopsin, saxitoxin analogues 1–6	animal mortality, PSP				Onodera *et al.* (1997b), Seifert *et al.* (2007)
Microcystis aeruginosa		Nostocophyceae	aeruginosin 298-A–B, microcystilide A, microcystin-LR, YR, RR etc. microginin, micropeptins A–B, 90, microviridin B–C	embryonic damage, toxic drinking water	Chl *a*	aphanizophyll, Calo, Cantha, ββ-Car, Cryp, Echin, isozeaxanthin, Myxo, Nosto, Oscil, Zea		Bagchi (1996), Carmichael (1997), Falconer (2007), Hertzberg *et al.* (1971), Oberholster *et al*. (2004), Paerl *et al.* (1983), Park *et al.* (1993), Pichardo *et al.* (2007), Walsh *et al.* (1997), Woitke *et al*. (1997)
Microcystis flos-aquae	*Polycystis flos-aquae*	Nostocophyceae		animal and chicken mortality				Fitch *et al.* (1934)

Microcystis panniformis		Nostocophyceae	microcystin-RR					Nguyen *et al.* (2007)
Microcystis viridis		Nostocophyceae	microcystins					Chan *et al.* (2007)
Microcystis wesenbergii		Nostocophyceae	microcystin-LR etc.	non-toxic or toxic	Chl *a*		allophycocyanin, phycocyanin	Braun and Bachofen (2004), Watanabe *et al.* (1988), Xing *et al.* (2007)
Nitzschia navis-varingica		Bacillariophyceae	domoic acid, isodomoic acid A–B	ASP				IOC, Kotaki *et al.* (2005), Lundholm and Moestrup (2000)
Noctiluca scintillans	*Medusa scintillans, Noctiluca miliaris*	Dinophyceae	ammonia	non-toxic or toxic, fish mortality			MAAs	Carreto *et al.* (2005), Lu and Hodgkiss (2004)
Nodularia spumigena	*Nodularia baltica, Nodularia litorea*	Nostocophyceae	nodularin, [Asp^{1}]-nodularin, [dhb^{5}]-nodularin, [CMAdda^{3}]-nodularin	animal mortality	Chl *a*	Cantha, ββ-Car, Cryp, Echin, Myxo	porphyra-334, shinorine (MAAs)	Laamanen *et al.* (2001), Mazur-Marzek *et al.* (2006), Moffit *et al.* (2001), Sinha *et al.* (2003)
Ostreopsis lenticularis		Dinophyceae	ostreotoxin 1, 3	neurotoxic				IOC, Tosteson *et al.* (1989)
Ostreopsis mascarenensis		Dinophyceae	mascarenotoxin A–B	neurotoxic				IOC, Lenoir *et al.* (2004)
Ostreopsis ovata		Dinophyceae	ovatoxin a, palytoxin	human distress				IOC, Ciminiello *et al.* (2006a), Ciminiello *et al.* (2008)
Ostreopsis siamensis		Dinophyceae	osterocin D	*Artemia* and human mortality, haemolysis, seafood poisoning				IOC, Onuma *et al.* (1999), Rhodes *et al.* (2000b), Ukena *et al.* (2001)
Phaeocystis globosa		Prymnesioph		haemolysis	Chl *a*,	But-fuco,		IOC, Peng *et al.*

		yceae			Chl c_1, Chl c_2, Chl c_3,	ββ-Car, βε-Car, Diadino, Diato, Fuco, Hex-fuco, Hex-kfuco		(2005), Rodríguez *et al.* (2006), Vaulot *et al.* (1994)
Phaeocystis pouchetii	*Tetraspora poucheti*	Prymnesiophyceae	*trans,trans*-deca-2,4-dienal	embryonic damage, fish mortality	Chl *a*	But-fuco, ββ-Car, Diadino, Diato, Fuco, Hex-fuco, Zea		IOC, Hansen *et al.* (2004), Nichols *et al.* (1991)
Phormidium tenue		Nostocophyceae		toxic to mice	Chl *a*		allophycocyanin, C-phycocyanin	Mohamed *et al.* (2006), Tang and Vincent (1999)
Planktothrix agardhii	*Oscillatoria agardhii, Planktothrix mougeotii*	Nostocophyceae	microcystins dMeLR, dMeRR, RR, YR, [ADMAdda^5]-microcystins 1–4	non-toxic or toxic	Chl *a*	ββ-Car, β,β-caroten-5,6-epoxide, Cryp, Echin, 3'-hydroxyechinenone, Myxo, Oscil, Zea		Briand *et al.* (2002), Hertzberg *et al.* (1971), Laub *et al.* (2002), Suda *et al.* (2002)
Planktothrix formosa	*Oscillatoria formosa, Phormidium formosum*	Nostocophyceae	homoanatoxin-a	neurotoxic				Furey *et al.* (2003)
Planktothrix mougeotii	*Oscillatoria mougeotii, Oscillatoria agardhii* var. *isothrix*	Nostocophyceae	anatoxin, microcystins					Kemka *et al.* (2003), Suda *et al.* (2002)
Planktothrix	*Oscillatoria rubescens*	Nostocophyc	anatoxin-a, [D-	fish and	Chl *a*	ββ-Car,	phycocy	Blom *et al.* (2006),

rubescens		eae	Asp^3]-microcystin-RR, [D-Asp^3,(*E*)-Dhb^7]-microcystin-HilR, [D-Asp^3,(*E*)-Dhb^7]-microcystin-RR, oscillapeptin J	zooplankton mortality		Cryp, Echin, 3'-hydroxyechinenone, Myxo, Oscil, Zea	anin, phycoerythrin	Briand *et al.* (2005), Ernst *et al.* (2007), Hertzberg and Liaaen-Jensen (1966a), Sano *et al.* (2004), Suda *et al.* (2002), Viaggiu *et al.* (2004), Welker and Erhard (2007)
Prorocentrum concavum	*Prorocentrum arabianum*	Dinophyceae	okadaic acid, two diol esters of okadaic acid, methyl ester of okadaic acid	DSP				Hu *et al.* (1992), Mohammad-Noor *et al.* (2007), Morton *et al.* (2002)
Prorocentrum donghaiense	*Prorocentrum dentatum* (misidentified?), *Prorocentrum shikokuensis*	Dinophyceae	oxygen depletion	fish mortality	Chl *a*	ββ-Car, Diadino, Peri		Hou *et al.* (2007)
Prorocentrum gracile	*Prorocentrum hentschelii*, *Prorocentrum sigmoides*	Dinophyceae	oxygen depletion	fish mortality				Lu and Hodgkiss (2004)
Prorocentrum hoffmannianum	*Exuviaella hoffmaniana (-num)*	Dinophyceae	okadaic acid	DSP				IOC, Faust (1990)
Prorocentrum lima	*Cryptomonas lima*, *Dinopyxis laevis*, *Exuviaella lima*, *Exuviaella marina* var. *Lima*	Dinophyceae	DTX 1–2, 4, okadaic acid, PL-toxins 1–3, various okadaic acid derivatives, various esters of okadaic acid and derivatives					Hu *et al.* (1992), Morton and Tindall (1995), Nascimento *et al.* (2005b), Paz *et al.* (2007a), Yasumoto *et al.* (1987)
Prorocentrum maculosum	*Exuviaella maculosa (-sum)*, *Prorocentrum*	Dinophyceae	DTX 5a, 5b, okadaic acid, prorocentrolide	DSP				IOC, Dickey *et al.* (1990), Hu *et al.*

	concavum (misidentified)		B					(1995), Hu *et al.* (1996)
Prorocentrum mexicanum	*Prorocentrum maximum* (not identical to *P. rhathymum)*	Dinophyceae		embryonic damage				Cortés-Altamirano and Sierra-Beltrán (2003), Naves *et al.* (2006)
Prorocentrum micans		Dinophyceae		non-toxic or toxic, DSP	Chl *a*	ββ-Car, Dino, Peri, Zea	MAAs	Cassie (1981), Grabowski *et al.* (2001), Johansen *et al.* (1974), Lesser (1996), Pavela-Vrančič *et al.* (2006), Tilstone *et al.* (2010)
Prorocentrum minimum	*Exuviaella apora, Exuviaella mariae-lebouriae, Exuviaella minima, Prorocentrum cordatum, Prorocentrum cordiformis, Prorocentrum mariae-lebouriae, Prorocentrum triangulatum*	Dinophyceae	oxygen depletion	non-toxic or toxic, fish and human mortality, neurotoxic, PSP	Chl *a*, Chl c_2, MgDVP	ββ-Car, Diadino, Diato, Dino, Peri, peridininol	MAAs	IOC, Heil *et al.* (2005), Johnsen and Sakshaug (1993), Rodríguez *et al.* (2006), Sinha *et al.* (1998)
Prorocentrum rhathymum		Dinophyceae		oyster larvae mortality				IOC, Pearce *et al.* (2005)
Protoceratium reticulatum	*Gonyaulax grindleyi*, *Peridinium reticulatum*	Dinophyceae	various yessotoxin and derivatives	non-toxic or toxic, toxic to shellfish	Chl *a*	Perid		IOC, Bowden (2006), Miles *et al.* (2005), Paz *et al.* (2007b), Rein and Snyder (2006), Rodríguez *et al.* (2007), Suzuki *et al.* (2007)

Prymnesium calathiferum		Prymnesiophyceae		fish mortality				IOC, Chang (1985)
Prymnesium parvum	*Prymnesium patelliferum (-ra)*	Prymnesiophyceae	prymnesin 1–2	algal and fish mortality	Chl *a*, Chl c_1, Chl c_2, Chl c_3, MGDG	ββ-Car, Diadino, Diato, Fuco, Viola		IOC, Larsen (1999), Rodríguez *et al.* (2006), Sasaki *et al.* (2006)
Pseudochattonella verruculosa	*Verrucophora farcimen, Chattonella* aff./cf. *verruculosa*	Dictyochophyceae	brevetoxins PbTx 2–3**, 9	fish mortality	Chl *a*, Chl c_1, Chl c_2, Chl c_3	But-fuco, Diadino, Diato, Fuco		IOC, Bourdelais *et al.* (2002), Edvardsen *et al.* (2007)
Pseudo-nitzschia australis	*Nitzschia pseudoseriata*	Bacillariophyceae	domoic acid, isodomoic acid C	ASP, sea lion mass mortality				IOC, Holland *et al.* (2005), Scholin *et al.* (2000)
Pseudo-nitzschia calliantha	*Nitzschia delicatula*, some *Nitzschia pseudodelicatissima*, some *Pseudo-nitzschia pseudodelicatissima*	Bacillariophyceae	domoic acid	non-toxic or toxic, ASP				IOC, Lundholm *et al.* (2003)
Pseudo-nitzschia delicatissima	*Nitzschia actydrophila, N. delicatula, N. pseudodelicatissima* (see also *P. calliantha*)	Bacillariophyceae	domoic acid? (identity of strains uncertain)					IOC, Lundholm *et al.* (2003)
Pseudo-nitzschia fraudulenta		Bacillariophyceae	domoic acid	non-toxic or toxic, ASP				IOC, Akallal *et al.* (2002), Rhodes *et al.* (1998)
Pseudo-nitzschia galaxiae		Bacillariophyceae	domoic acid	weakly toxic, ASP				IOC, Cerino *et al.* (2005)
Pseudo-nitzschia multiseries	*Nitzschia pungens* f. *multiseries, Pseudo-nitzschia pungens* f. *multiseries*	Bacillariophyceae	domoic acid	ASP			MAAs	IOC, Bates *et al.* (2004), Carreto *et al.* (2005), Hagström *et al.* (2007)
Pseudo-nitzschia multistriata		Bacillariophyceae	domoic acid	non-toxic or toxic, ASP				IOC, Orsini *et al.* (2002), Rhodes *et*

								al. (2000a)
Pseudo-nitzschia pseudodelicatissima	Recently divided into several species; see e.g. Amato *et al.* (2007); *Nitzschia pseudodelicatissima*	Bacillariophyceae	domoic acid	ASP				IOC, Amato *et al.* (2007), Trainer *et al.* (2007)
Pseudo-nitzschia pungens	*Nitzschia pungens*	Bacillariophyceae	domoic acid	non-toxic or toxic, ASP				IOC, Casteleyn *et al.* (2008)
Pseudo-nitzschia seriata	*Nitzschia seriata, Pseudo-nitzschia seriata* f. *seriata*	Bacillariophyceae	domoic acid	ASP				IOC, Fehling *et al.* (2004)
Pseudo-nitzschia turgidula	*Nitzschia turgidula*	Bacillariophyceae	domoic acid	non-toxic or toxic, ASP				IOC, Rhodes *et al.* (1998)
Pyrodinium bahamense	*Gonyaulax schilleri, Pyrodinium schilleri*	Dinophyceae	decarbamoylsaxitoxin, gonyautoxin 5–6 (B1-B2), neosaxitoxin, saxitoxin	PSP				IOC, Gedaria *et al.* (2007), Harada *et al.* (1982a), Harada *et al.* (1982b)
Radiocystis fernandoi	*Radiocystis feernandoi*	Nostocophyceae	microcystin-LR					Lombardo *et al.* (2006)
Raphidiopsis curvata	*Raphidopsis curvata*	Nostocophyceae	cylindrospermopsin, deoxycylindrospermopsin					Li *et al.* (2001)
Raphidiopsis mediterranea		Nostocophyceae	anatoxin-a, 2,3-epoxyhomoanatoxin-a, homoanatoxin-a	neurotoxic				Namikoshi *et al.* (2003), Namikoshi *et al.* (2004)
Schizothrix calcicolata		Nostocophyceae	debromoaplysiatoxin	human eye and skin distress, shrimp gastrointestinal damage				Pérez-Linares *et al.* (2003)
Scrippsiella trochoidea	*Glenodinium trochoideum, Peridinium trochoideum*	Dinophyceae	oxygen depletion	fish mortality				Hallegraeff (1992)

Skeletonema spp.	*Skeletonema costatum* (recently divided into several species)	Bacillariophyceae	oxygen depletion	fish gill lesions and mortality	Chl *a*, Chl c_1, Chl c_2	ββ-Car, Diadino, Diato, Fuco		Brunet *et al.* (1996), Kent *et al.* (1995)
Takayama tasmanica	*Gymnodinium pulchellum, Gyrodinium acrotrochum, Gyrodinium cladochroma*	Dinophyceae		fish mortality	Chl *a*, Chl c_2, Chl c_3	ββ-Car, Diadino, Diato, Fuco		IOC, de Salas *et al.* (2003)
Thalassiosira spp.		Bacillariophyceae		fish gill lesions and mortality	Chl *a*, Chl c_1, Chl c_2	ββ-Car, Diadino, Diato, Fuco		Kent *et al.* (1995), Yao *et al.* (2006)
Trichodesmium erythraeum		Nostocophyceae	ammonia (from decaying cells), microcystins, oxygen depletion	copepod, fish, oyster and shrimp mortality	Chl *a*	ββ-Car, Echin, Myxo, Zea	phycoerythrin	Carpenter *et al.* (1993), Negri *et al.* (2004), Ramos *et al.* (2005)
Trichodesmium thiebautii		Nostocophyceae		copepod mortality	Chl *a*	ββ-Car, Echin, Myxo, Zea	phycoerythrin	Carpenter *et al.* (1993), Hawser *et al.* (1992)
Tychonema bourrellyi	*Oscillatoria bornetii* f. *tenuis, Oscillatoria bourrellyi, Tychonema tenue*	Nostocophyceae	oxygen depletion				phycocyanin, phycoerythrin	Ganf *et al.* (1991), Heaney *et al.* (1996)
Umezakia natans		Nostocophyceae	cylindrospermopsin	heptatotoxic				Vasas *et al.* (2002)

* *Chattonella antiqua* and *C. ovata* are now considered varieties of *C. marina* and are no longer considered as separate species (Demura *et al*., 2009)

** Not all strains produce PBTx2 or 3: Dr Lesley Rhodes, Senior Research Scientist, Cawthron Institute, New Zealand

*** Recent work indicates other *Gambierdiscus* species also produce toxins: *G. australes* (Rhodes *et al*., 2010) and *G. polynesiensis* (Chinain *et al*., 2010)

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