Algae
Volume 17(4): 283-292, 2002

Chaetomorpha Balls Foul New Hampshire, USA Beaches

Arthur C. Mathieson* and Clinton J. Dawes[1]

Department of Plant Biology and Jackson Estuarine Laboratory University of New Hampshire, Durham, NH 03824, USA and
[1]*Department of Biology, University of South Florida, Tampa, Fl 33620, USA*

Large populations of green balls washed ashore at Plaice Cove on North Beach, Hampton, New Hampshire, USA during June, 2002 and were reported in various local and national newspapers and magazines. The thread-like green alga *Chaetomorpha picquotiana* made up 79% of the balls' fresh weight, which averaged 26.6 ± 3.8 g and 5.9 ± 0.3 cm in diameter. Based on photographs, there were about 223 balls m^{-2} on North Beach on June 12 that had disappeared by early July, 2002. The balls contained 30 species, including 20 seaweeds, 2 flowering plants, and 8 invertebrates. By contrast, quadrat samples (625 cm^2) taken on the same beach during late June 2002 included 16 species of seaweeds, of which *C. picquotiana* was the second most common one, plus 3 species of flowering plants, and 3 species of invertebrates. The enhanced number of invertebrates in the balls compared with those in the quadrats suggests that they serve as a refuge and source of food. Production of the algal balls appears to be based on wave activity, shape and hardness of the nearshore shoreline, light penetration, temperature, and nutrients. Massive entangled mats of drift *C. picquotiana* (60.3-1453 g fresh wt. m^{-2}) occurred in September 2002 during one of the warmest summers on record in New England.

Key Words: aegagropilous, algal blooms, *Chaetomorpha picquotiana*, green balls, Gulf of Maine, New Hampshire, USA, seaweeds

INTRODUCTION

The present paper reports the occurrence of extensive green balls, or aegagropilous seaweed populations (Norton and Mathieson 1983), from two New Hampshire, USA beaches. Tens of thousands of these balls washed ashore at North Beach (Plaice Cove), Hampton (Fig. 1) during mid summer of 2002, disappearing shortly thereafter. Newspaper and magazine reports included speculation that they were everything from extra-terrestrial life, to a unique phytoplankton, entangled masses of plastic string, Brillo pads ®, seagrass fibers, and finally seaweeds (Anonymous 2002a-g; Bergeron, 2002). Sensational headlines about aegagropilous seaweeds have been reported elsewhere (Norton and Mathieson 1983), including "mystery balls" at Torbay in Great Britain (Newton 1950) and "sea manure" at Nahant near Boston, Massachusetts (Anonymous 1903; Wilce *et al*. 1982). In discussing these *Cladophora* balls at Torbay, Newton (1950) notes that they occur sporadically, sometimes cast up in enormous numbers and at other times totally absent. By contrast, Wilce *et al*. (1982) describes a long, persistent history associated with the nuisance ball-forming brown alga *Pilayella littoralis* (L.) Kjellman at Nahant, which produces extensive sludge-like masses up to 0.5m thick. When buried in sand, primarily in winter, the algal sludge eventually decomposes and in warm weather produces noxious volatile sulfides.

Aegagropilous seaweeds are distinctive loose-lying forms that consist of radially arranged branches (filaments) of either individual or multiple plants entangled together into spherical balls (Kjellman 1893; Dickinson 1933; Norton and Mathieson 1983). Some of the best known examples are the "lake balls" produced by several species of the green alga *Cladophora* (Kjellman 1898; Lorenz 1901; Brand 1902; Acton 1916; Nakazawa and Abe 1973; Kurogi 1980a,b; Kanda 1982) and designated as "Special Natural Monuments" in Japan (Kurogi 1980b). Similar balls are also formed by several marine species of *Cladophora*, as well as at least 54 other seaweeds, including 25 red, 18 green and 11 brown algae (Norton and Mathieson 1983; Mathieson *et al*. 2000).

*Corresponding author (arthur@hopper.unh.edu)

Fig. 1. Extensive drift populations of *Chaetomorpha* balls occurring at Plaice Cove on North Beach, Hampton, New Hampshire, USA during mid-June, 2002.

Typically, the balls represent compacted aggregates of tangled filaments that are infertile and reproduce vegetatively. Most aegagapilous seaweeds, such as the "beach-form" or ecad *mackaii* (Turner) Cotton of the fucoid brown alga *Ascophyllum nodosum* (L.) Le Jolis, begin their development as attached plants. Aegagropilous morphologies result from a variety of factors, including detachment / breakage, oscillating movement of fragmented materials, meristematic injury, scar tissue development, and extensive regeneration and / or proliferation of new growth (Fritsch 1935, 1945; Gibb 1957; Yoshida 1963; Sakai 1964; Nakazawa and Abe 1973; Mathieson *et al*. 2000). Subsequent rolling and further injury cause pruning, proliferation, and compaction, resulting in a dense, spherical structure (Norton and Mathieson 1983; Mathieson *et al*. 2000).

In describing the initial "invasion" of these green balls at North Beach (Plaice Cove), Hampton it was noted that their occurrence was due to several factors, including the presence of "a deep gorge just offshore", plus the fact that "storm surges wash things around on the bottom before they end up on a high tide being washed up on the beach" (Anonymous 2002b). In contrast to the implied recent occurrence of these balls, several local lobstermen reported that their traps frequently became filled with balls if set too close to shore, particularly after a major storm (Anonymous 2002b; Bergeron 2002). They also noted that the green filaments were so tough that they had to be cut off with a knife. Thus, the balls are probably more ubiquitous than initially thought, occasionally cast ashore in large numbers after periods of extensive breakage and growth of parental, perennial material. In the present account we characterize the occurrence and demography of these green balls from New Hampshire, USA, compare them with other aegagropilous populations, and discuss their possible origin.

MATERIALS AND METHODS

The temporal and spatial occurrence of the algal balls were determined from long-term seasonal studies at nine nearshore open coastal sites from Portsmouth to Hampton, New Hampshire, USA between 1965 and 2002 (Mathieson and Hehre 1986; Mathieson and Penniman 1991). The nine study sites (Fig. 2) extended from Hampton Beach State Beach, Hampton (42°54'30"N,

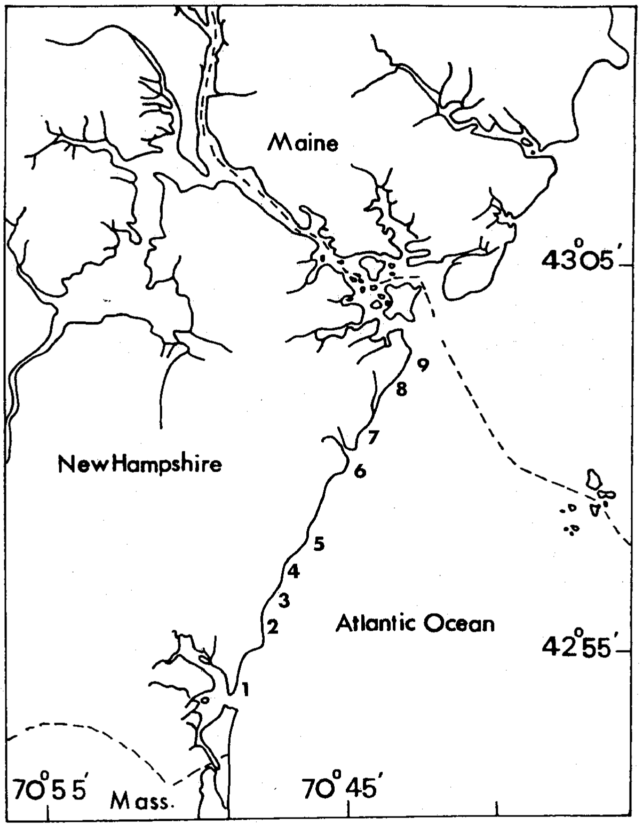

Fig. 2. The New Hampshire, USA coastline showing the location of nine study sites numbered from south to north: (1) Hampton Beach State Beach (42°54'30"N, 70°48'30"W); (2) a sandy beach midway between Hampton Beach State Park and Bicentennial Park, Hampton (42°54'40"N, 70°Δ48'50"W); (3) Bicentennial Park, Hampton (42°54'50"N, 70°48'55"W); (4) Plaice Cove on North Beach (42°56'10"N, 70°47'50"W); (5) North Hampton State Beach, Hampton (42°57'20"N, 70°46'40"W); (6) Jenness State Beach, Rye (42°59'10"N, 70°45'40"W); (7) Rye North Beach, Rye (43°00'05"N, 70°44'30"W): (8) North Wallis Sands, Rye (43°01'25"N, 70°43'40"W); (9) Odiorne's Point, at Frost Point, Portsmouth (43°02'15"N, 70°43'20"W).

70°48'30"W) in the south to Odiorne's Point, at Frost Point, Portsmouth (43°02'15"N, 70°43'20"W) in the north.

Thirty-two balls were collected in mid-June 2002 at North Wallis Sands, Rye and North Beach, Hampton where abundant populations were originally present. An enumeration of their mean (± S.E) shape, diameter, fresh weight, species composition, and biomass contributions was made. The biological components of the balls were enumerated under a dissecting scope (40-100X magnification). Invertebrate identification and nomenclature primarily follow Pollock (1998), Smith (1964) and Weiss (1995), while seaweed identifications are based upon synopses given by Blair (1983), Choi *et al.* (2001), Kingsbury (1969), Maggs and Hommersand (1993), Maggs *et al.* (2002), Sears (2002), Taylor (1957), and Villalard-Bohnsack (1995). Seaweed nomenclature primarily follows Sears (2002) and South and Tittley (1986).

Three random quadrat samples (625 cm^2) were collected from the drift line at North Beach during mid-June 2002 in order to characterize the species composition and biomass of individual taxa, plus possible "seed material." Mean biomass values (± S.E.) for total and individual biomass contributions were enumerated. The density of balls at North Beach was also estimated by comparing their numbers in several photographs (Fig. 1), using the balls' mean diameter (see above) for size. During early September 2002 massive populations of entangled green algal filaments (*Chaetomorpha picquotiana* Montagne) occurred on the nearshore open coast of New Hampshire, stimulating an evaluation of species composition and biomass at the nine study sites by the same quadrat sampling (625 cm^2) procedures described above.

RESULTS

Chronology

A few small green balls were initially collected at North Wallis Sands Beach during March of 2002. Subsequently, extensive populations of larger balls occurred over a 300m length of shoreline at North Beach near Plaice Cove on June 12, 2002 where they averaged about 223 m^{-2} (Fig. 1). By early July only sporadic and localized populations were present. In September 2002, the nearshore open coast of New Hampshire was fouled by extensive populations of entangled filamentous masses of *Chaetomorpha picquotiana* (Fig. 3) and only a few residual balls were present within the upper wrack zone (see below).

Construction of the balls

Figure 4 gives a comparison of the 32 balls collected during mid-June; most of the balls were spherical in shape (ca 84.4 %) and only a few were oval (ca 15.6%). They ranged in size (diameter) from a golf to a tennis ball (i.e. about 3.0 & 7.0 cm, respectively), with a mean value of 5.9 ± 0.3 cm. The ball's fresh weight averaged 26.6 ± 3.8 g. The mean number of taxa in a ball was 10.3 ± 0.46; most of these were plant fragments (8.1 ± 0.26 taxa) of various green (1.9 ± 0.12), brown (0.38 ± 0.096), and red algae (6.22 ± 0.86), plus some flowering plants (0.97 ± 0.06). The number of invertebrate taxa / ball aver-

Fig. 3. Extensive drift populations of entangled *Chaetomorpha picquotiana* at Plaice Cove on North Beach, Hampton, New Hampshire, USA during early September, 2002.

aged 2.5 ± 0.21.

Although not illustrated, the June 2002 ball samples from North Beach were larger and heavier (i.e. 7.1 ± 0.4 cm and 76.9 ± 4.5 g fresh wt.) than those from North Wallis Sands (i.e. 5.5 ± 0.3 and 20.2 ± 2.9 g fresh wt.). The former specimens were the size of tennis balls, while the latter were smaller and golf-ball like. The March 2002 North Wallis Sands samples were also relatively small and golf-ball like.

Fragments of 30 species were found in the balls (Table 1). Twenty-two of these were plants (79%), including 4 green, 2 brown and 14 red algae, plus 2 flowering plants. Eight invertebrates were recorded (21% of total taxa). The thread-like green alga *Chaetomorpha picquotiana* was the major biological component of each ball (100% occurrence), with a mean biomass contribution of 70.9% ± 3.6%. Sand particles occurred in most balls (78.3 ± 10.7%) and only a few had pebbles (22.9 ± 9.2%). The five most common taxa in the balls, expressed as percent occurrence, were *C. picquotiana* (100%), *Spartina patens* (Aiton) Muhl. (93.8%), *Chondrus crispus* Stackhouse (90.6%), *Tubularia larynx* Ellis et Solander (75.0%), and *Chaetomorpha linum* (O. F. Muller) Kützing (71.9%).

Patterns of drift biomass

The mid-June 2002 biomass quadrats from North Beach averaged 7.6 ± 0.76 kg fresh wt. m^{-2}. Three invertebrates and 19 plant taxa occurred in the quadrats (Table 1), including 1 green, 6 brown and 9 red algae, plus 3 flowering plants. The five dominant species were *Ascophyllum nodosum* (L.) Le Jolis (1912 ± 1065.6 g fresh wt. m^{-2}), *Chaetomorpha picquotiana* (1159.9 ± 410 g fresh wt. m^{-2}), *Fucus vesiculosus* L. (889.6 ± 422.4 g fresh wt. m^{-2}), *Laminaria saccharina* (L.) J.V. Lamouroux (798.4 ± 665.6 g fresh wt. m^{-2}), and *Chondrus crispus* (606.4 ± 207.2 g fresh wt. m^{-2}). Thus, *C. picquotiana* contributed ~ 15.3 % of the total drift, second only to *A. nodosum*.

A comparison of mid-June 2002 drift biomass (*i.e.* quadrat) and percent occurrence (*i.e.* ball) data (Table 1) showed several interesting patterns: (1) *Chaetomorpha pic-*

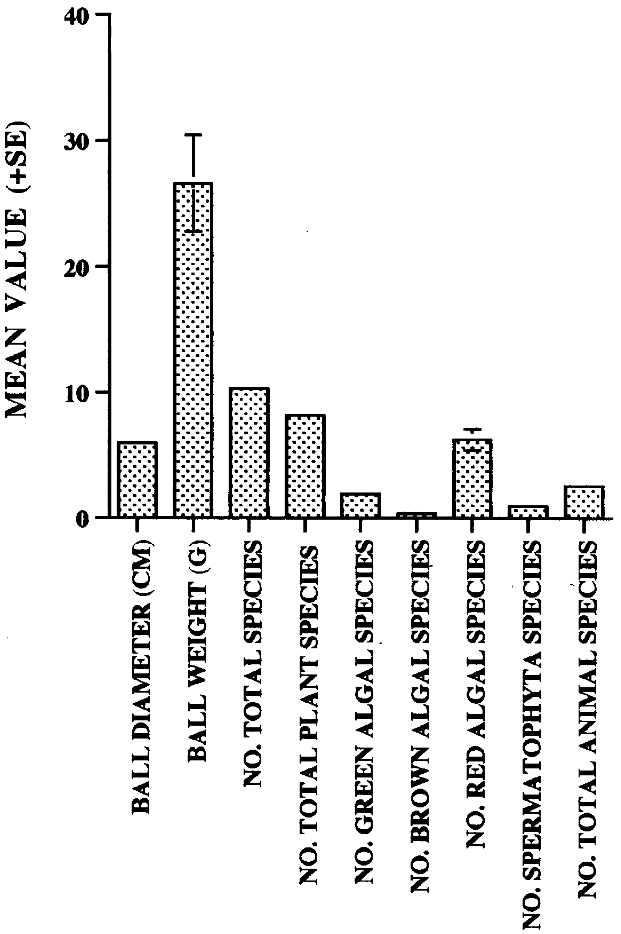

Fig. 4. Characteristics of thirty-two *Chaetomorpha* balls, including their mean (+ SE) diameter, fresh weight and composition with respect to total number of taxa and number of various plant (algae and Spermatophyta) and invertebrate taxa.

quotiana was abundant in both types of samples; (2) the number of species in the balls was greater than in the quadrat samples (30 versus 22), with this same pattern evident for green and red algae, plus the invertebrates; (3) the number of brown algal taxa was greater in the quadrats than the balls (6 versus 2); (4) the conspicuous fucoid and kelp plants found in the quadrats (*i.e. Ascophyllum nodosum*, *Fucus vesiculosus*, and *Laminaria saccharina*) were relatively inconspicuous in the balls; (5) the number of Spermatophyta was low and similar in both samples (3 versus 2); (6) the diverse red algal flora of the balls did not show a corresponding biomass pattern in the quadrat samples; (7) several small invertebrate taxa were restricted to the balls and absent in the quadrat samples; (8) only two invertebrates were found in both types of samples (the hydroids *Sertularia pumila* L. and *Tubularia larynx*), while the sponge *Halichondria panicea* (Pallas) was restricted to the biomass quadrats.

Massive populations of drift seaweeds occurred on New Hampshire beaches during September 2002, being much greater than in mid-June of the same year (Fig. 3). For example, at North Beach drift populations during September were ~130X greater than in mid-June, with these two periods averaging 990.3 ± 193 kg and 7.6 ± 0.76 kg fresh wt. m^{-2}, respectively (Fig. 5). Pronounced spatial differences were also evident in September, with biomass values ranging from 1453.7 ± 64.4 kg fresh wt. m^{-2} at North Hampton State Beach to 60.3 ± 10.6 kg fresh wt. m^{-2} midway between Hampton Beach State Park and Bicentennial Park. Thus, the sandy mid coastal areas (i.e. North Beach & North Hampton State Beach) had peak biomass values, while the sites to the north and south had reduced values. In comparing the major contributors of biomass at the nine sites, entangled rope-like populations of the green alga *Chaetomorpha picquotiana* were the most abundant drift populations (56.6-91%), with an overall mean of 73.3%, excluding the North Wallis Sands site where large brown algae (i.e. fucoids & kelps) replaced this green alga (i.e. 84.5%). The general correspondence between total and *C. picquotiana* biomass is readily apparent, with reduced contributions by brown and red algae (Fig. 5). In contrast to the early summer when ball-forming populations of *C. picquotiana* were common, they were rare in September.

DISCUSSION

To our knowledge, this is the first record of *Chaetomorpha picquotiana* having an aegagropilous habit (Fig. 1), as previous reports have only described entangled or loose-lying populations (Taylor 1957; Blair 1983; Norton and Mathieson 1983; Sears 2002). The plant's major center of distribution is in northern North America (Blair 1983) where it occurs from Long Island Sound to Newfoundland and Labrador on the east coast and Oregon to Alaska on the west coast; a few records of the plant have also been confirmed from Florida and Bermuda. The species distribution is very similar to that of *C. melagonium* (F. Weber and D. Mohr) Kützing. In the Gulf of Maine drift and entangled populations of *C. picquotiana* are common, with a mean biomass of 0.54 ± 0.28 kg fresh wt. m^{-2} during 1994-2001 (Mathieson, unpublished data). Recent biomass values for North Beach during mid-June (1.16 ± .040 kg fresh wt. m^{-2}) and early September, 2002 (806.7 ± 180 kg fresh wt. m^{-2}) are much higher, being 2.1 and 1488 times the earlier records,

Table 1. Mean (± SE) biomass values for individual plant and animal taxa from drift populations (n= 3) at North Beach, New Hampshire, USA expressed as g fresh wt. m^{-2}. The percent occurrence of individual taxa within thirty-two algal balls from North Beach, New Hampshire and North Wallis Sands, New Hampshire is also shown, plus the total number of taxa in both the biomass and ball samples.

TAXA / GROUP	BIOMASS OF QUADRATS	% OCCURRENCE IN BALLS
PLANTS		
CHLOROPHYTA		
Chaetomorpha linum (O.F. Müller) Kützing	0	71.9
Chaetomorpha picquotiana Montage *ex* Kützing	1151.9 ± 410.0	100
Rhizoclonium tortuosum (Dilwyn) Kützing	0	18.8
Ulva lactuca L.	0	3.1
# CHLOROPHYTA TAXA: BIOMASS SAMPLES (1 SPECIES); BALL SAMPLES (4 SPECIES)		
PHAEOPHYTA		
Agarum clathratum Dumort	441.6 ± 360.0	0.0
Ascophyllum nodosum (L.) Le Jolis	1912 ± 1065.6	3.1
Desmarestia aculeata (L.) J.V. Lamouroux	125.9 ± 62.4	34.4
Fucus spiralis L.	84.8 ± 84.8	0.0
Fucus vesiculosus L.	889.6 ± 422.4	0.0
Laminaria saccharina (L.) J.V. Lamouroux	798.4 ± 665.6	0.0
# PHAEOPHYTA TAXA: BIOMASS SAMPLES (6 SPECIES); BALL SAMPLES (2 SPECIES)		
RHODOPHYTA		
Ahnfeltia plicata (Hudson) Fries	49.9 ± 49.9	68.8
Callophyllis cristata (C. Agardh) Kützing	0.0	12.5
Ceramium virgatum Roth	0.0	21.9
Chondrus crispus Stackhouse	606.4 ± 207.2	90.6
Corallina officinalis L.	2.2 ± 2.2	65.6
Cystoclonium purpureum (Hudson) Batters	0.0	37.5
Mastocarpus stellatus (Stackhouse) Batters	0.0	6.3
Membranoptera alata (Hudson) Stackhouse	0.0	3.1
Neosiphonia harveyi (J. Bailey) Kim, Choi, Guiry et Saunders	123.8 ± 85.6	12.5
Phycodrys rubens (L.) Batters	30.2 ± 26.9	0.0
Phyllophora pseudoceranoides (Gmelin) Newroth et Taylor	168.9 ± 89.8	0.0
Polyides rotundus (Hudson) Greville	50.6 ± 31.7	0.0
Polysiphonia lanosa (L.) Tandy	110.4 ± 59.2	34.4
Polysiphonia stricta (Dillwyn) Greville	0.0	53.1
Rhodomela confervoides (Hudson) P. Silva	0.0	3.1
Titanoderma corallinae (P. et H. Crouan) Woelkerling, Y.M. Chamberlain *et* P.C. Silva	0.0	25.0
Titanoderma pustulatum (J.V. Lamouroux) Woelkerling, Y.M. Chamberlain *et* P.C. Silva	15.9 ± 15.9	59.4
# RHODOPHYTA TAXA: BIOMASS SAMPLES (9 SPECIES); BALL SAMPLES (14 SPECIES)		
SPERMATOPHYTA		
Quercus wood & leaf fragments	294.4 ± 294.4	3.1
Spartina alterniflora Loisel.	78.6 ± 40.0	0.0
Spartina patens (Aiton) Muhl.	0.0	93.8
Zostera marina L.	2.3 ± 2.3	0.0
# SPERMATOPHYTA TAXA: BIOMASS SAMPLES (3 SPECIES); BALL SAMPLES (2 SPECIES)		
ANIMALS		
PORIFERA		
Halichondria panicea (Pallas)	411.2 ± 412.8	0.0

Table 1. continued

TAXA / GROUP	BIOMASS OF QUADRATS	% OCCURRENCE IN BALLS
HYDROZOA		
Obelia commissuralis McCrady	0.0	28.1
Sertularia pumila L.	45.3 ± 45.4	15.6
Tubularia larynx Ellis *et* Solander	11.4 ± 11.4	75.0
MOLLUSCA: BIVALVIA		
Mytilus edulis L.	0.0	68.8
MOLLUSCA: GASTROPODA		
Lacuna vincta (Montagus)	0.0	6.3
POLYCHAETA		
Spirobis borealis Daudin	0.0	21.8
CRUSTACEA: ISOPODA		
Idotea baltica (Pallas)	0.0	3.1
ECHINODERMATA		
Strongylocentrotus droebachiensis (O.F. Müller)	0.0	34.4
# ANIMAL TAXA: BIOMASS SAMPLES (3 SPECIES); BALL SAMPLES (8 SPECIES)		
#TOTAL PLANT AND ANIMAL TAXA: BIOMASS SAMPLES (22 SPECIES); BALL SAMPLES (30 TAXA)		

respectively (Fig. 3). Whatever the specific amounts, the "seed material" for aegagropilous *C. picquotiana* appears to be widely distributed, abundant, and present year round (Mathieson and Hehre 1986). The occurrence of massive amounts of entangled *C. picquotiana* during the late summer (September) of 2002 is particularly noteworthy, as it occurred during the third warmest summer on record in New England (Anon. 2002h; pers. comm., New Hampshire State Climatology Dept., Durham, New Hampshire and Bureau of Commercial Fisheries Laboratory, Boothbay, Maine). Hence, future occurrences of these green balls might well be expected.

In discussing the origin of aegagropilous populations of *Chaetomorpha picquotiana* it should be noted that it is initially attached by a "modestly differentiated basal cell" (Blair 1983). Upon breakage, the plant develops into entangled rope-like masses within the lower littoral / upper sublittoral (Taylor 1957; Mathieson and Hehre 1986). The transition between entangled filamentous masses and compacted balls in *C. picquotiana* must involve fragmentation, proliferation, compaction, and rolling on the bottom of the ocean. Further an optimum amount of water movement must be required (Yoshida 1963; Nakazawa and Abe 1973; Norton and Mathieson 1983). If too little, the plant remains undisturbed; if too much, it is either swept away or abraded and destroyed. Continual agitation (overturning) is also essential to maintain a spherical shape and to prevent decay of any portions on sedimented surfaces (Gibb 1957).

As outlined by Norton and Mathieson (1983), the *Posidonia* seagrass balls that are so characteristic of the Mediterranean (Oltmanns 1923; Cannon 1979) are formed by the aggregation of fibrous detritus, while aegagropilous seaweeds are produced from living plant materials. Even so, the mode of origin and composition of aegagropilous seaweeds, like the brown alga *Halopteris funicularis* (Montagne) Sauvageau, is comparable to that of *Posidonia* balls because accretion is purely mechanical through an accumulation of plant debris around a core of extraneous matter, such as small shells and the exoskeleton of several invertebrates (Dickinson 1933). The occurrence of sand, pebbles, and shell fragments, plus several plants and invertebrates in the *Chaetomorpha* balls (Table 1) suggests an analogous accumulation and accretion process, and that they serve as a refuge and source of food for selected invertebrates. In discussing ball formation in freshwater species of the green alga *Cladophora*, Chapman and Chapman (1973) note that balls are only found nearshore, while "thread" and "cushion" forms occur in greater depths where there is less water motion. Also, the harder the lake bottom the more regular the shape of the balls. The rarity of aega-

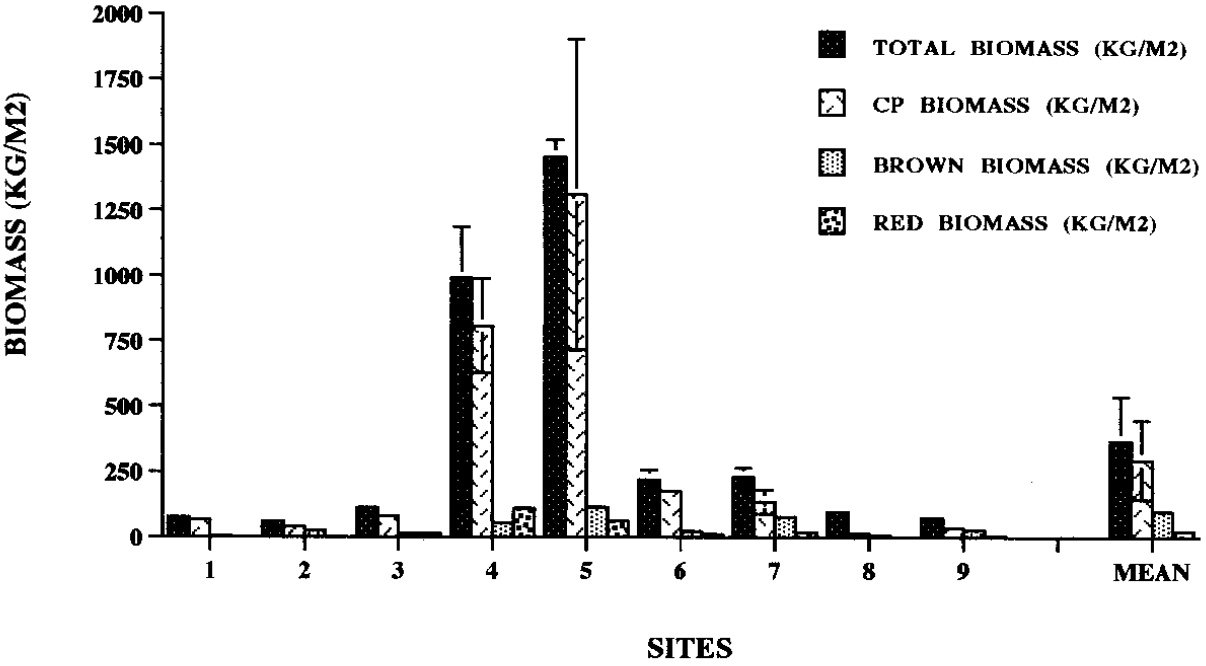

Fig. 5. Drift biomass populations of seaweeds at nine nearshore open coastal sites in New Hampshire, USA, plus their overall mean values, expressed as kg fresh wt. m^{-2}; a delineation of total biomass is given, plus biomass contributions by the green alga *Chaetomorpha picquotiana* (CP) and various brown and red algae. See Fig. 2 for site designations and locations.

gropilous populations of *Chaetomorpha* spp. (Norton and Mathieson 1983) suggests specific environmental conditions, including strong water motion, nearness to shore for adequate light penetration, optimal temperatures, and the availability of nutrients that would allow rapid growth and proliferation. The occurrence of very warm temperatures during massive blooms of detached *C. picqotiana* was previously noted; the extensive geographical nature of this build-up (Fig. 5) suggests that temperature rather than nutrients may have been a key factor producing this "seed material".

A comparison of aegagropilous populations of *Chaetomorpha picquotian*a and the temperate brown alga *Desmarestia aculeata* (L.) J.V. Lamouroux (Mathieson *et al.* 2000) shows some interesting parallels. Both New England USA populations were collected in areas of strong water motion; the former occurred near a deep gorge (Anonymous 2002b; Bergeron 2002) and the latter within deep tide pools or semi-enclosed tidal channels that provided consistent movement (rolling) and compaction. An analogous pattern is also present for detached populations of the tropical and subtropical seaweeds *Caulerpa racemosa* (Forsskål) J. Agardh and *Bryothamnion seaforthii* (Turner) Kützing that form ball-shaped masses after exposure to gentle water motion near coral reefs and within mangrove canals (Almodovar and Rehn 1971). Both *C. picquotiana* and the *D. aculeata* spheres were the size of tennis balls and contained a diverse assemblage of plants, animals, exoskeletons, and shell fragments. By contrast, two other common bloom-forming temperate aegagropilous seaweeds, *Pilayella littoralis* and *Spermothamniuon repens* (Dillwyn) Rosenvinge, form much smaller balls (Wilce *et al.* 1982).

ACKNOWLEDGMENTS.

We thank several individuals who helped with the present study. Cindy Ibechem collected the first samples of *Chaetomorpha* balls from North Wallis Sands. Dr. Jon Pennock is acknowledged for his help in obtaining some samples, plus several comments and suggestions. Dr. Edward Hehre reviewed an earlier version of this manuscript, while Dr. Fred Short discussed various aspects of the study and provided several photographs. Ellen Goethel summarized many personal observations at North Beach, as well as provided several photographs. Heather Talbot is thanked for taking several habitat pictures during the September 2002 algal bloom. This paper is issued as Contribution Number 393 from the Jackson Estuarine Laboratory and the Center for Marine Biology.

REFERENCES

Acton E. 1916. On the structure and origin of *Cladophora*-balls. *New Phytol.* **15:** 1-10.

Almodovar L.R. and Rehm A. 1971. Marine algal balls at La Parguera, Puerto Rico. *Nova Hedwigia* **21:** 255-259.

Anonymous. 1903. Lynn Dailey Evening Item, August 19, 1903.

Anonymous. 2002a. Thousands of mysterious balls wash up on North Beach. Foster's Daily Democrat, June 18 2002, p. 3A.

Anonymous. 2002b. Green balls are just grass. Foster's Daily Democrat, June 19 2002, pp. 1, 6.

Anonymous. 2002c. The sea tells us how little we know. Foster's Daily Democrat, June 20, 2002, p. 4A.

Anonymous. 2002d. Final word: its seaweed, not sea grass. Manchester Union Leader, June 25, 2002, p. B10.

Anonymous. 2002e. Green fiber balls are seaweed, not grass. Foster's Daily Democrat, June 25, 2002, p. 3A.

Anonymous. 2002f. UNH scientists say mysterious beach balls are seaweed. Valley News, June 25, 2002, p. A2

Anonymous. 2002g. Green balls of algae? The Boston Globe, June 27 2002, p. 2.

Anonymous. 2002h. Forecast for 2102: warmer, smoggier. Univ. New Hampshire Magazine fall 2002, p. 11.

Bergeron E. 2002. The green globes. *Popular Science* **261:** 31.

Blair S.1983. Taxonomic treatment of the *Chaetomorpha* and *Rhizoclonium* species (Cladophorales: Chlorophyta) in New England. *Rhodora* **85:** 175-211.

Brand F. 1902. Die *Cladophora*-Aegagropilen des Süsswasers. *Hedwigia* **41:** 34-71.

Cannon J.F.M. 1979. An experimental investigation of *Posidonia* balls. *Aquat. Bot*. **6:** 407-410.

Chapman V.J. and Chapman D.J. 1973. *The Algae*, 2nd ed. Macmillan Press, London, New York, 334 pp.

Choi H.-G., Kim M.-S., Guiry M.D. and Saunders G.W. 2001. Phylogenetic relationships of *Polysiphonia* (Rhodomelaceae, Rhodophyta) and its relatives based on anatomical and nuclear small-subunit rDNA sequence data. *Can. J. Bot*. **79:** 465-1476.

Dickinson C.I. 1933. Some marine algal balls from Tasmania. *Ann. Bot.* **47:** 253-259.

Fritsch F.E. 1935. *The Structure and Reproduction of the Algae*, Vol. I. Cambridge Univ. Press, Cambridge, England, 791 pp.

Fritsch F.E. 1945. *The Structure and Reproduction of the Algae*, Vol. II. Cambridge Univ. Press, Cambridge, England, 939 pp.

Gibb D.C. 1957. The free-living forms of *Ascophyllum nodosum* (L.) Le Jolis. J. Ecol. 45: 49-83.

Kanda F. 1982. A new form of *Cladophora sauteri* from Lake Toro in the Kushira moor, Hokkaido. *Jap. J. Phycol*. **30:** 147-153.

Kingsbury J.M. 1969. *The seaweeds of Cape Cod and the Islands.* Chatham Press Inc., Chatham, MA, 212 pp.

Kjellman F.R. 1893. Studier ofver Chlorophyceslagter *Acrosiphonia* J.G. Ag. Bih. K. Svensk. *Vet. Akad. Handl.* **18**, Afd. 3, No. 5.

Kjellman F.R. 1898. Zur Organographie und Systematik der Aegagropilen. *Nov. Act. Reg. Soc. Sci. Upsala Ser*. **3:** 1-26.

Kurogi M. 1980a. Artificial lake ball, "Marimo", of a green alga *Cladophora sauteri*. *Jap. J. Phycol*. **28:** 128-129.

Kurogi M. 1980b. Lake ball "Marimo" in Lake Alan. *Jap. J. Phycol*. **28:** 168-169.

Lorenz J.R. 1901. Ergänzungen zur Bildungsgeschichte der sogennanten "Seeknödel" (*Aegagropila sauteri* Kg.). *Verh. Zool.-Bot. Ges. Wien* **51:** 363-368.

Maggs C.A. and Hommersand M.H. 1993. *Seaweeds of the British Isles*, Vol. 1. Rhodophyta. Part 3a: Ceramiales. British Museum (Natural History), London, England, 444 pp.

Maggs C.A., Ward B.A., McIvor L.M., Evans C.M., Rueness J. and Stanhope M.J. 2002. Molecular analyses elucidate the taxonomy of fully corticated, nonspiny species of *Ceramium* (Ceramiaceae, Rhodophyta) in the British Isles. *J. Phycol.* **41:** 409-420.

Mathieson A.C. and Hehre E.J. 1986. A synopsis of New Hampshire seaweeds. *Rhodora* **88:** 1-139.

Mathieson A.C. and Hehre E.J. and Dawes C.J. 2000. Aegagropilous *Desmarestia aculeata* from New Hampshire. *Rhodora* **102:** 202-207.

Mathieson A.C. and Penniman P.A. 1991. Floristic patterns and numerical classification of New England estuarine and open coastal seaweed populations. *Nova Hedwigia* **52:** 453-485.

Nakazawa S. and Abe M. 1973. Artificial globing of algae. *Jap. J. Phycol*. **21:** 53-56.

Newton L.M. 1950. A beach-ball mystery at Torbay. Illustrated London News 216, p. 98.

Norton T.A. and Mathieson A.C. 1983. The biology of unattached seaweeds. In. Round F.E. and Chapman D.J. (eds). *Progress in Phycological Research*, Vol. 2, Elsevier Scientific Publ. Co., Amsterdam, Netherlands. pp. 333-386.

Oltmanns F. 1923. *Morphologie und Biologie der Algen*, Vol. III, 2nd ed., G. Fisher, Stuttgart, 558 pp.

Pollock L.W. 1998. *A Practical Guide to the Marine Animals of Northeastern North America.* Rutgers University Press, New Brunswick, NJ, 367 pp.

Sakai Y. 1964. The species of *Cladophora* from Japan and its vicinity. *Sci. Pap. Inst. Algol. Res. Fac. Sci. Hokkaido Imp. Univ*. **5:** 1-104.

Sears J.R. (ed.) 2002. *NEAS Keys to Benthic Marine Algae of the Northeastern Coast of North America from Long Island Sound to the Strait of Belle Isle.* Contrib. 2, Northeast Algal Society, Dartmouth, MA, 161 pp.

Smith R.I. (ed.) 1964. *Keys to Marine Invertebrates of the Woods Hole Region*. Marine Biological Laboratory, Woods Hole, Mass, 208 pp.

South G.R. and Tittley I. 1986. *A Checklist and Distributional Index of the Benthic Algae of the North Atlantic Ocean*. Spec. Publ. Huntsman Mar. Lab. and British Museum (Natural Hist.), St. Andrews, New Brunswick and London, 76 pp.

Taylor W.R. 1957. *Marine Algae of the Northeastern Coast of North America*. University of Michigan Press, Ann Arbor, MI, 509 pp.

Villalard-Bohnsack M. 1995. *Illustrated Key to the Seaweeds of New England*. Rhode Island Natural History Survey, Kingston, RI, 145 pp.

Weiss H.M. 1995. *Marine Animals of Southern New England and New York. Idenfication Keys to Common Nearshore and Shallow Water Macrofauna*. Bulletin of the State Geological and Natural History Survey of Connecticut, Dept. Environmental Protection, Bull. 115, Hartford, Conn, 327 pp.

Wilce R.T., Schneider C.W., Quinlan A.V. and Bosch K.V. 1982. The life history and morphology of free-living *Pilayella littoralis* (L.) Kjellm. (Ectocarpaceae, Ectocarpales) in Nahant Bay, Massachusetts. *Phycologia* **21:** 336-354.

Yoshida T. 1963. Studies on the distribution and drift of the floating seaweeds. *Bull. Tohoku Reg. Fish Res. Lab.* **23:** 141-186.

Accepted 30 September 2002