

ALGAL DIVERSITY AT OTTER CLIFFS

A COMPARISON OF CURRENT SPECIES TO THOSE LISTED IN JOHNSON AND SKUTCH 1928

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Introduction

For this project, we were asked to find and compare the algal species in certain tide pools at Otter Cliffs with those found by Johnson and Skutch (1928). Estimating the locations of the tide pools was a confusing task, and pictures were held up in an attempt to match them with our location. All species of algae found were collected, identified, and compared with the species list from 1928.

Figure 1: Aerial view of Otter Cliff from Google Maps compared with the sketch of the aerial view of the same point shown in Johnson and Skutch 1928



The Satellite image of Otter Cliff was captured to compare it with the sketch used by Johnson and Skutch. The coordinates of Otter Cliffs they have included in their paper are 44° 19' N and 68° 11' W. Three tide pools were identified by us, that we think are those studied by Johnson and Skutch. The large tide pool coordinates are as follows:

Southeast side: 19T0564708

Northwest side: 19T0564697

West: 19T0564700

East: 19T0564706

Dimensions: 70' 6" x 44' 2"

The two smaller tide pools had the following coordinates:

Southwest side: 19T0564702

Northeast side: 19T0564707

Dimensions: 35' 3" x 17' 6"

Dimensions: 19' 8" x 14' 4"

The tide pool map given in the paper is shown below:

Figure 2: Map of the tide pools at Otter Cliff during low tide, sketched by Johnson and Skutch

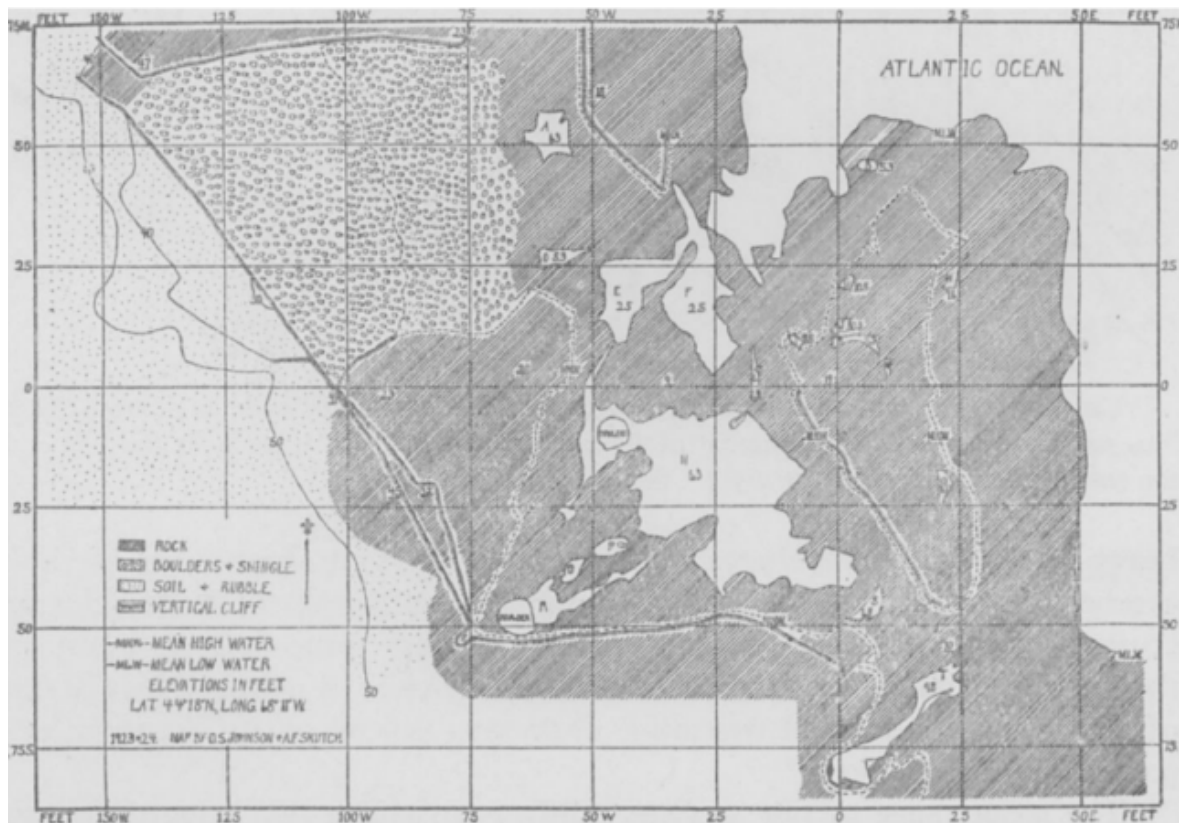


Figure 3: A picture of the tide pools in 2013.



These smaller tide pools were merging, therefore there isn't a vast difference in their coordinates. As can be seen in the sketch of the tide pools from Figure 2, the smaller tide pools to the left of the larger one merge.

Figure 4: A picture from Johnson and Skutch (1928) showing a view from the tide pools.



Figure 5: A picture of the same location from 2013



As you can see from Figure 4 and 5, the locations are extremely similar. However, the image from 1928 shows rocks covered in hundreds of barnacles. The same location 85 years later shows significantly fewer signs of barnacles.

In his book *Marine Botany* (2nd edition 1998), Clinton J. Dawes writes of another study conducted in reference to Johnson and Skutch 1928- “An earlier study of zonation at this site (Johnson and Skutch, 1928) determined elevations, and the same site was reexamined in 1996 using the original benchmark.” Dawes’ records have also been represented in the table below, along with Johnson and Skutch 1928 and our collections from 2013.

Table 1: Showing all the algal species found collectively in 2013, 1996 (by Dawes), and in 1928 (by Johnson and Skutch)

Species	Johnson and Skutch 1928	Dawes 1996	2013
<i>Acrosiphonia arcta</i>			X
<i>Agarum clathratum</i>			X

<i>Agarum turneri</i>	X		
<i>Ahnfeltia plicata</i>		X	
<i>Alaria esculenta</i>	X	X	X
<i>Ascophyllum nodosum</i>	X	X	X
<i>Bangia fuscopurpurea</i>	X		
<i>Calothrix crustacea</i>	X		
<i>Calothrix scopulorum</i>	X		
<i>Calothrix sp.</i>			X
<i>Ceramium botryocarpum</i>	X		
<i>Ceramium nodulosum*</i>		X	
<i>Chaetomorpha melagonium</i>	X		
<i>Chaetomorpha Sp.</i>			X
<i>Chondrus crispus</i>	X	X	X
<i>Chordaria flagelliformis</i>	X		
<i>Cladophora constricta</i>	X		
<i>Cladophora sp.</i>			X
<i>Clathromorphum circumscriptum</i>		X	
<i>Codiolum longipes</i>	X		
<i>Codiolum pusillum</i>		X	
<i>Corallina officinalis</i>	X		X

<i>Ectocarpus littoralis</i> *	X		
<i>Elachistea fucicola</i>	X		X
<i>Elachistea lubrica</i> *	X		
<i>Enteromorpha compressa</i> *	X		
<i>Enteromorpha intestinalis</i> *	X	X	X
<i>Enteromorpha micrococca</i> *	X		
<i>Enteromorpha minima</i> *	X	X	
<i>Fucus distichus</i> spp. <i>edentatus</i> *		X	
<i>Fucus filiformis</i>	X		
<i>Fucus furcatus</i> *	X		X
<i>Fucus spiralis</i>		X	
<i>Fucus vesiculosus</i>	X	X	X
<i>Gigartina mamilliosa</i> *	X	X	X
<i>Halosaccion ramentaceum</i> *	X	X	
<i>Hormiscia penicilliformis</i> *	X	X	
<i>Hormiscia Wormskjoldii</i>	X		
<i>Laminaria digitata</i>	X	X	X
<i>Laminaria saccharina</i> *		X	
<i>Leathesia difformis</i> *	X		

<i>Melobesia Lenormandi*</i>	X		
<i>Monostroma Grevillei</i>	X		
<i>Petalonia fascia</i>	X		
<i>Petrocelis cruenta*</i>	X	X	X
<i>Polysiphonia fastigiata*</i>	X		X
<i>Polysiphonia harveyi*</i>		X	
<i>Polysiphonia urceolata*</i>		X	
<i>Polysiphonia violacea*</i>	X		X
<i>Porphyra miniata</i>			X
<i>Porphyra umbilicalis</i>	X	X	
<i>Ralfsia verrucosa</i>	X		
<i>Rhizoclonium tortuosum</i>	X		
<i>Rhodomela confervoides</i>		X	
<i>Rhodymenia palmata*</i>	X	X	X
<i>Saccorhiza dermatodea</i>	X		
<i>Scytosiphon lomentarius*</i>	X		
<i>Spongomorpha arcta</i>	X		
<i>Spongomorpha hystrix</i>	X		

<i>Spongomorpha sp.</i>			X
<i>Spongomorpha spinescens*</i>	X	X	
<i>Ulothrix flacca</i>	X	X	
<i>Ulothrix sp.</i>	X		
<i>Ulva lactuca</i>	X	X	X
<i>Ulvaria obscura</i>		X	
<i>Verrucaria striatula</i>	X		

Species with a * have updated names. See Appendix B.

Table 2: Table showing the zonation of algal species

a) Within the tide pools

	Johnson and Skutch 1928	Dawes 1996	2013
<i>Ahnfeltia plicata</i>		X	
<i>Alaria esculenta</i>	X	X	X
<i>Ceranium botryocarpum</i>	X		
<i>Ceranium nodulosum</i>		X	
<i>Chaetomorpha melagonium</i>	X		
<i>Cladophora sp.</i>			X
<i>Clathromorphum circumscriptum</i>		X	
<i>Corallina officinalis</i>	X		X
<i>Corallina spp.</i> (encrusting)			X
<i>Devaleraea ramentacea</i>		X	

<i>Fucus evanescens</i>		X	
<i>Laminaria digitata</i>		X	X
<i>Laminaria saccharina</i>		X	
<i>Leathesia difformis</i>	X		
<i>Melobesia lenormandi</i>	X		
<i>Petrocelis cruenta</i>		X	
<i>Neosiphonia harveyi</i>		X	
<i>Polysiphonia stricta</i>	X	X	
<i>Rhizoclonium tortuosum</i>	X		
<i>Rhodomela confervoides</i>		X	
<i>Rhodymenia palmata</i>	X		X
<i>Saccorhiza dermatodea</i>	X		
<i>Spongomorpha hystrix</i>	X		
<i>Spongomorpha spinescens</i>		X	
<i>Spongomorpha spp.</i>			X
<i>Ulva intestinalis</i>			X
<i>Ulva lactuca</i>			X
<i>Ulvaria obscura</i>		X	

b) Lower intertidal

	Johnson and Skutch 1928	Dawes 1996	2013
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<i>Chondrus crispus</i>	X	X	X
<i>Chordaria flagelliformis</i>	X		
<i>Devaleraea ramentacea</i>	X		
<i>Fucus distichus</i>	X		X
<i>Mastocarpus stellatus</i>	X	X	
<i>Palmaria palmata</i>	X	X	X
<i>Petalonia fascia</i>	X		
<i>Pylaiella littoralis</i>	X		
<i>Ralfsia verrucosa</i>	X		
<i>Scytosiphon lomentaria</i>	X		
<i>Spongomorpha arcta</i>	X		
<i>Spongomorpha spinescens</i>	X		
<i>Ulva lactuca</i>	X	X	

c) Upper intertidal

	Johnson and Skutch 1928	Dawes 1996	2013
<i>Ascophyllum nodosum</i>	X	X	X
<i>Blidingia minima</i>	X	X	
<i>Calothrix sp.</i>			X
<i>Codiolum pusillum</i>		X	
<i>Ulva intestinalis</i>		X	
<i>Fucus filiformis</i>	X		
<i>Fucus spiralis</i>		X	
<i>Fucus vesiculosus</i>	X	X	X

<i>Porphyra miniata</i>			X
<i>Porphyra umbilicalis</i>	X	X	
<i>Ulothrix flacca</i>		X	
<i>Urospora penicilliformis</i>		X	

NOTE: The zonation of many species found by Johnson and Skutch (1928) was not included in the second part of their paper (Littoral Vegetation on a Headland of Mt. Desert Island, Maine. II. Tide-Pools and the Environment and Classification of Submersible Plant Communities) and hence were not marked. Example: *Polysiphonia fucoides*

Northern rock barnacles (*Semibalanus balanoides*) cover most of the *upper intertidal* zone. They are mostly exposed during low tide, although a small number of barnacles remain below the tide line. A mixture of *Fucus vesiculosus* and *Ascophyllum nodosum* are found in the *lower intertidal* zone. These algae dominate this area and are found partly below and partly above the tide line at low tide. *Littorina obtusata* was the species of periwinkle found in this region.

Within the tide pools, encrusting *Corallina* covers much of the floor. Upright *Corallina officinalis* is also very abundant. Plentiful amounts of *Chondrus crispus* and *Ulva lactuca* are evenly spread throughout the tide pools. *Ulva intestinalis* is found in small amounts.

Small numbers of *Tealia felina* are found in protected areas, such as behind or under rocks. At a point between two tide pools, a small cavelike crevice is formed underneath a large rock. *Tealia felina*, *Halichondria panicea*, and *Asteria rubens* are found within this protected crevice (See Figure 6). *Halichondria panicea* is not found anywhere else in the tide pools.

The smaller tide pools, which are located nearest the ocean, contain the most species diversity. *Cladophora sp.*, for example, is only found in these pools, and in very small amounts. This could have been brought in by the waves during high tide. A similar reason could be used to explain the presence of certain species found by Johnson and Skutch in 1928, for example- *Cladophora constricta*, an algae not even found in the Gulf of Maine could have been brought in by boats. Another example is *Polysiphonia fucoides*, which was found growing attached to a rock, but in extremely small quantities.

Figure 6



Figure 7: 2013 picture of the larger tide pool



Figure 8: 2013 picture of species zonation around larger tide pool



Hypothesis: Natural History as a Cause for Change and other reasons

From 1928 to 2013, the substrate at Otter cliffs has undergone a lot of changes influenced by several factors such as the Maine Fire of 1947, pollution from boats, increase in tourism, etc. The fire could have destroyed several species, having had an effect despite not really reaching Otter Point. The fire wiped out several species around Otter Point, which could have affected food chains. Also, the impact of the change in temperature on organisms in the upper intertidal could have brought their populations to being endangered or at a risk. Secondary succession after the fire could have changed food chains drastically, introducing more predators or eliminating them. One example could be the vast presence of barnacles on the rocks at the location in 1928, as can be seen in Figure 4. The number of barnacles in 2013 at the same location has declined considerably, and the Fire of 1947 could be one reason for this.

Other reasons could be climate change and introduction of predators such as the Green Crab, *Carcinus maenas*, which according to the State of the Gulf of Maine Report on Marine Invasive Species (June 2010) expanded its population up into the Gulf of Maine from waters south of Cape Cod Massachusetts. In fact, they reason this to be because of climate change, saying “Changes in climate resulting in warmer winter water temperatures in particular could provide a thermal refuge for invading species and may have important impacts to timing of recruitment and survival.”

The effect on even one species that is part of the marine interaction web at Otter Cliffs could have created change. One particularly intriguing example is that of *Cladophora constricta*, which was mentioned in the species list in Johnson and Skutch 1928. According to information from algaebase.org and marinespecies.org, this species of algae is not found in the Gulf of Maine but is instead found further south in the Atlantic Islands, the Caribbean Islands and Indian Ocean Islands like the Seychelles. This could have happened with southward movement of tides, or with the species being outcompeted by other algae that are more resistant to the cold. Another reason could be that they identified a species

incorrectly.

Mis-identification is a reason for why we couldn't locate the same species as Johnson and Skutch did in 1928. Species such as *Hormiscia Wormskjoldii* could not be found on the internet, apart from one reference mentioned in Appendix A.

Conclusion and Limitations

To conclude, several species of algae were collected from tide pools that were identified as those previously studied by Johnson and Skutch in 1928 at Otter Cliffs. These were then identified and matched with those listed in their paper. Any differences in species found was noted, and reasons for change were hypothesized above.

There were several limitations we faced with this project. To begin with, the research was not adequate to confidently compare the algal species. There wasn't enough time spent looking at other tide pools in the area and attempting to match different locations to the one studied in the paper by Johnson and Skutch 1928.

The time period in which the research was carried out by us (Late September- October) is not the same as the time period of the research by Johnson and Skutch (the month of August). Species diversity can vary with season.

Also, we could have missed sighting some species that were very low in the tide pools or behind massive rocks. Certain species that might have been present in very small populations could have been washed off or destroyed by waves and the tides.

Greater magnification on microscopes could have provided us with the opportunity to properly distinguish between certain species by examining internal cell structure.

Opportunity for Further Study and Feasibility

There are chances that the tide pools we collected algae from are not the same ones studied by Johnson and Skutch in 1928. However, we believe that they are the same tide pools because several species found were the same, and more importantly the pictures from the papers by Johnson and Skutch matched the tide pools and rocks at the location we were at.

Given the adequate monetary compensation, provision of housing and food, the study of Algal Diversity at Otter Cliffs can be carried, hopefully successfully, and provide us with a substantial comparison to the species found by Johnson and Skutch in 1928. This would be helpful in assessing the natural history of the area of Otter Cliffs and making available an updated database to those wishing to carry out studies in the area.

The data collected by Clinton J. Dawes in 1996 has also been included in the comparisons in

our project, and this gives us an idea of how species diversity and zonation might have changed over time. With a much more detailed study of Otter Cliffs in the near future, comparisons with older records such as these will pave the way for a timeline, making it easier to observe changes and reason the movement in algal species and its effects on biodiversity.

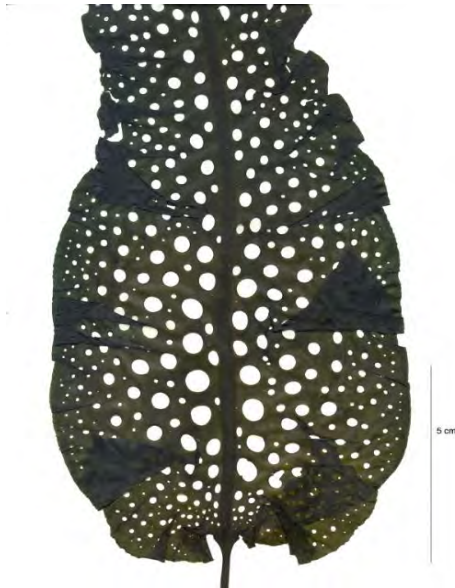
An important point to note would be that these comparisons might lead to the discovery of significant changes that could be potential indicators of climate change, which is very important in education, policy making, etc.

Literature Cited:

- Dawes, C. J. (1998). Macroalgal Communities. *Marine Botany* (pp. 218-220). New York, NY: John Wiley & Sons, Inc.. (Original work published 1997) from http://books.google.co.in/books?id=IHGIL7az7p0C&pg=PA220&lpg=PA220&dq=otter+cliffs+algae&source=bl&ots=qA2_D-XUMx&sig=ohMYmrZtbC5CfaBUpGUMKnmHkN8&hl=en&sa=X&ei=JU2AUv25Ko_nsATa64CoCA&ved=0CDoQ6AEwAQ#v=onepage&q=otter%20cliffs%20algae&f=false
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- Pappal, A. (2010). Marine Invasive Species. *State of the Gulf of Maine Report*, n.a.. Retrieved November 21, 2013, from <http://www.gulfofmaine.org/state-of-the-gulf/docs/marine-invasive-species.pdf>

Appendix A: List of Algae species mentioned in Johnson and Skutch 1928

1. *Agarum turneri*



2. *Alaria esculenta*



3. *Ascophyllum nodosum*



4. *Bangia fuscopurpurea*



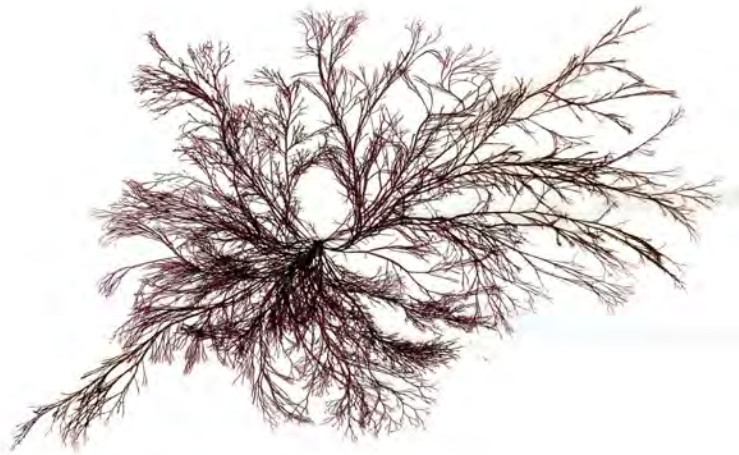
5. *Calothrix crustacea*



6. *Calothrix scopulorum*



7. *Ceramium botryocarpum*



8. *Chaetomorpha melagonium*



9. *Chaetomorpha* sp.



10. *Chondrus crispus*



11. *Chordaria flagelliformis*



12. *Cladophora constricta*

No longer found in the Gulf of Maine, is found further south in the Gulf of Mexico and Seychelles Islands.

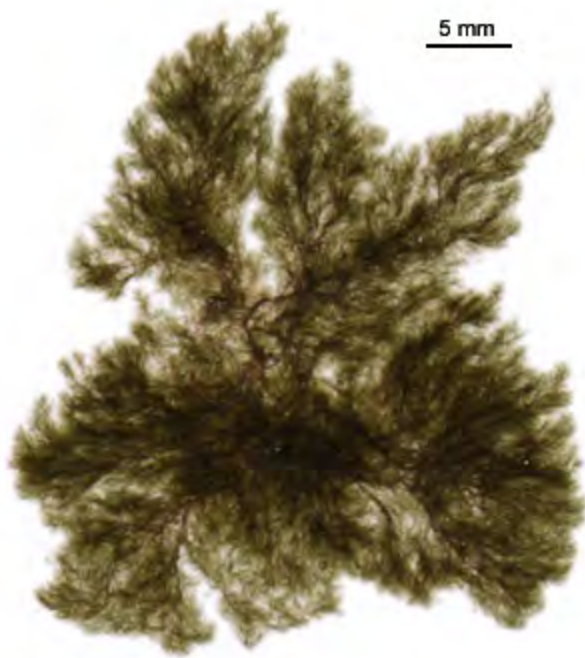


13. *Codiolum longipes*: http://www.algaebase.org/search/species/detail/?species_id=102652

14. *Corallina officinalis* (upright and encrusting)

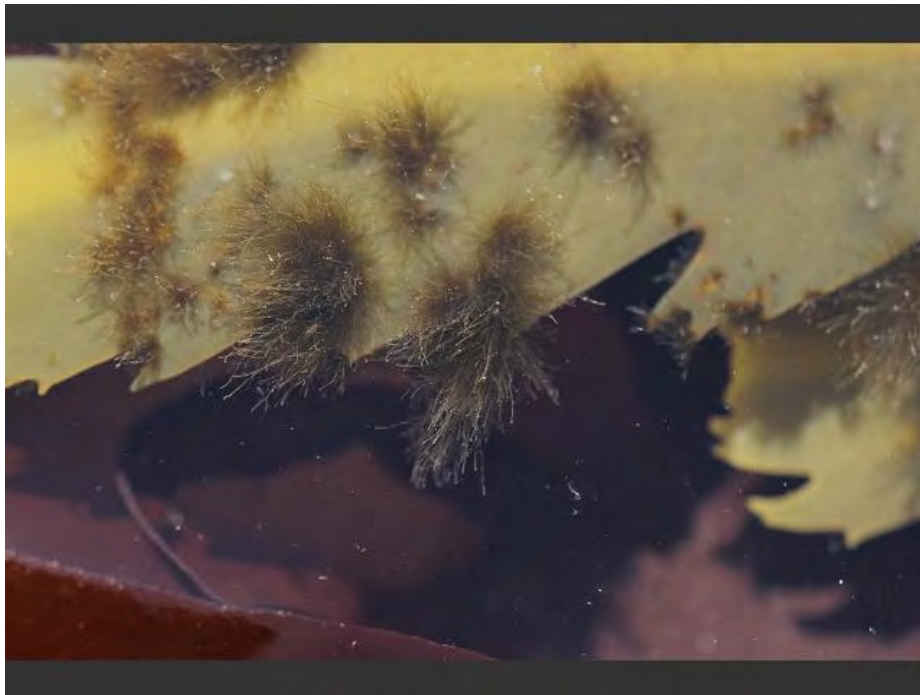


15. *Pylaiella littoralis*



Tristan Le Goff

16. *Elachista fucicola*



18. *Enteromorpha compressa* (L.) Greville

Now accepted as *Ulva compressa*. Similar to *U.intestinalis*, only in this species the edges are

“ruffled” while in *U.intestinalis* the edges are straight and smooth. Also, in some types the ribbons are branched at the base. Found in the Gulf of Maine.

ID: http://www.flora.sa.gov.au/efsa/algae_revealed/pdf/Enteromorpha_compressa.pdf

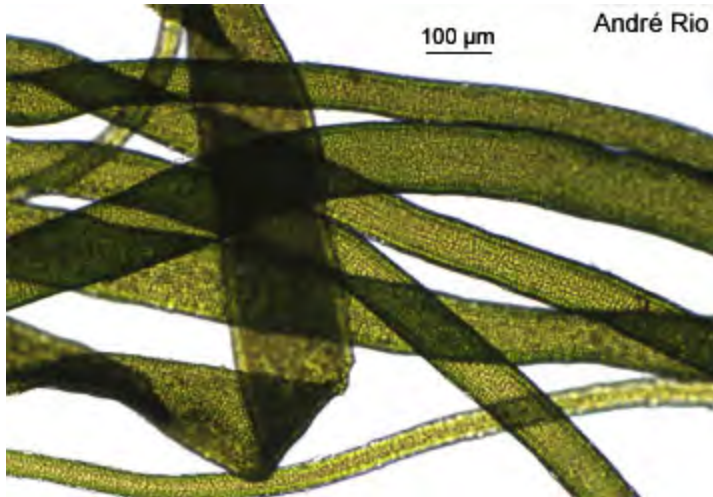


19. *Enteromorpha intestinalis* à *Ulva intestinalis*



20. *Enteromorpha micrococca* Kützinger

Now accepted as *Blidingia marginata* (J.Agardh) P.J. L. Dangeard, 1958
Found in the Gulf of Maine



21. *Enteromorpha minima* Nägeli in Kützing

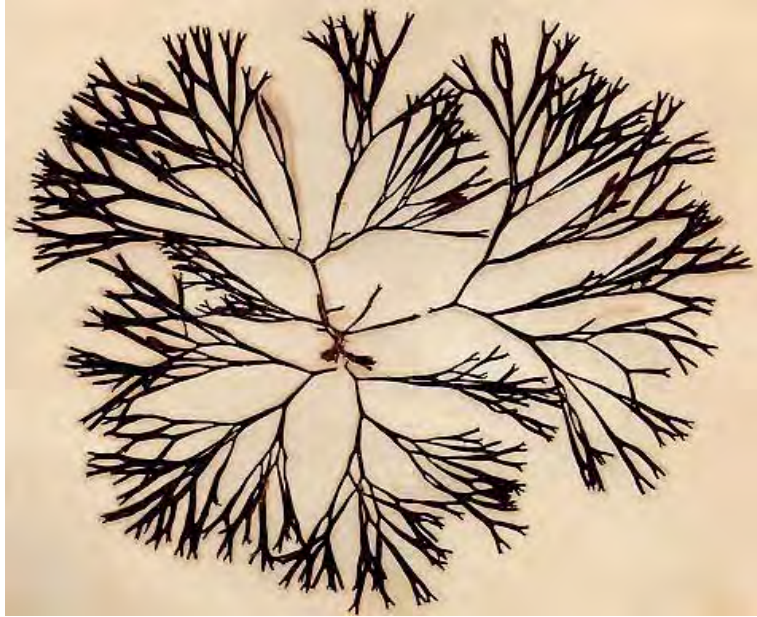
Now known as *Blidingia minima* (Nägeli ex Kützing) Kylin, 1947



22. *Fucus filiformis* S. G. Gmelin

23. *Fucus furcatus* Ag.

Now known as *Fucus distichus* Linnaeus, 1767 Found in the Gulf of Maine



24. *Gigartina mamillosa* (Goodenough & Woodward) J. Agardh, 1851
 Now accepted as *Mastocarpus stellatus* (Stackhouse) Guiry, 1984 – False Irish Moss. Found in GoM



25. *Halosaccion ramentaceum* (L.) J. Agardh, 1852
 Now accepted as *Devaleraea ramentacea* (L.) Guiry, 1982 found in the Gulf of Maine



26. *Hormiscia penicilliformis* (Roth.) Fries

Now accepted as *Urospora penicilliformis* (Roth) Areschoug, 1866 See:

http://cfb.unh.edu/phycokey/Choices/Chlorophyceae/green_seaweeds/UROSPORA/Urospora_Image_page.htm



27. *Hormiscia Wormskjoldii* (Mert.) Fries

http://books.google.co.in/books?id=79xJAAAAAYAAJ&pg=PA196&img=1&zoom=3&hl=en&sig=ACfU3U09DkLoNMnvBWxw8dvA8C_5uW24Nw&ci=99%2C1139%2C864%2C281&edge=0
<http://books.google.co.in/books?id=79xJAAAAAYAAJ&pg=PA197&img=1&zoom=3&hl=en&sig=ACfU3U2BwgE0sAD-QnYEAJTe-QhFDtLStQ&ci=121%2C182%2C695%2C760&edge=0>

Not on Marinespecies.org

28. *Laminaria digitata* (Tum.) Lamx.

Laminaria digitata (Hudson) J.V.Lamouroux, 1813



29. *Leathesia difformis* (L.) Aresch.

Now accepted as *Leathesia marina* (Lyngbye) Decaisne, 1842 – found in the Gulf of Maine



30. *Melobesia Lenormandi* Aresch

Now accepted as *Phymatolithon lenormandii* (Areschoug) W.H.Adey, 1966 – found in the Gulf of Maine



31. *Monostroma Grevillei* (Thuret) Wittrock
Found in the Gulf of Maine



32. *Petalonia fascia* (O.F Müll.) Kuntze
Found in the Gulf of Maine



34. *Polysiphonia fastigiata*

Now accepted as *Vertebrata lanosa*



35. *Polysiphonia violacea*

Now accepted as *Polysiphonia fucoides*



36. *Porphyra umbilicalis*



37. *Ralfsia verrucosa*



38. *Rhizoclonium tortuosum*



39. *Rhodymenia palmate*

Now accepted as *Palmaria Palmata*



40. *Saccorhiza dermatodea*



41. *Scytosiphon lomentarius*

Now accepted as *Scytosiphon lomentaria*



42. *Spongomorpha arcta*



43. *Spongomorpha hystrix*



44. *Acrosiphonia spinescens* (*Spongomorpha spinescens*)



45. *Ulothrix flacca*



46. *Ulothrix* sp.



47. *Ulva Lactuca*



48. *Verrucaria striatula*



Appendix B: Change in algae names from 1928 - 2013

Johnson and Scutch 1928	Change in Name - 2013
<i>Ceramium nodulosum</i>	<i>Ceramium virgatum</i>
<i>Ectocarpus littoralis</i>	<i>Pylaiella littoralis</i>
<i>Elachistea lubrica</i>	<i>Elachistea fucicola</i>
<i>Enteromorpha compressa</i>	<i>Ulva compressa</i>
<i>Enteromorpha intestinalis</i>	<i>Ulva intestinalis</i>
<i>Enteromorpha micrococca</i>	<i>Blidingia marginata</i>
<i>Enteromorpha minima</i>	<i>Blidingia minima</i>
<i>Fucus distichus</i> spp. <i>edentatus</i>	<i>Fucus evanescens</i>
<i>Fucus furcatus</i>	<i>Fucus distichus</i>
<i>Gigartina mammosa</i>	<i>Mastocarpus stellatus</i>
<i>Halosaccion ramentaceum</i>	<i>Devaleraea ramentacea</i>
<i>Hormiscia penicilliformis</i>	<i>Urospora penicilliformis</i>

<i>Laminaria saccharina</i>	<i>Saccharina latissima</i>
<i>Leathesia difformis</i>	<i>Leathesia marina</i>
<i>Melobesia Lenormandi</i>	<i>Phymatolithon lenormandii</i>
<i>Petrocelis cruenta</i>	<i>Mastocarpus stellatus</i>
<i>Polysiphonia fastigiata</i>	<i>Vertebrata lanosa</i>
<i>Polysiphonia harveyi</i>	<i>Neosiphonia harveyi</i>
<i>Polysiphonia urceolata</i>	<i>Polysiphonia stricta</i>
<i>Polysiphonia violacea</i>	<i>Polysiphonia fucoides</i>
<i>Rhodymenia palmata</i>	<i>Palmaria palmata</i>
<i>Scytosiphon lomentarius</i>	<i>Fucus lomentarius</i>
<i>Spongomorpha spinescens</i>	<i>Acrosiphonia spinescens</i>