Marine Invasive Species and Changes in Benthic Ecology in the Gulf of Maine

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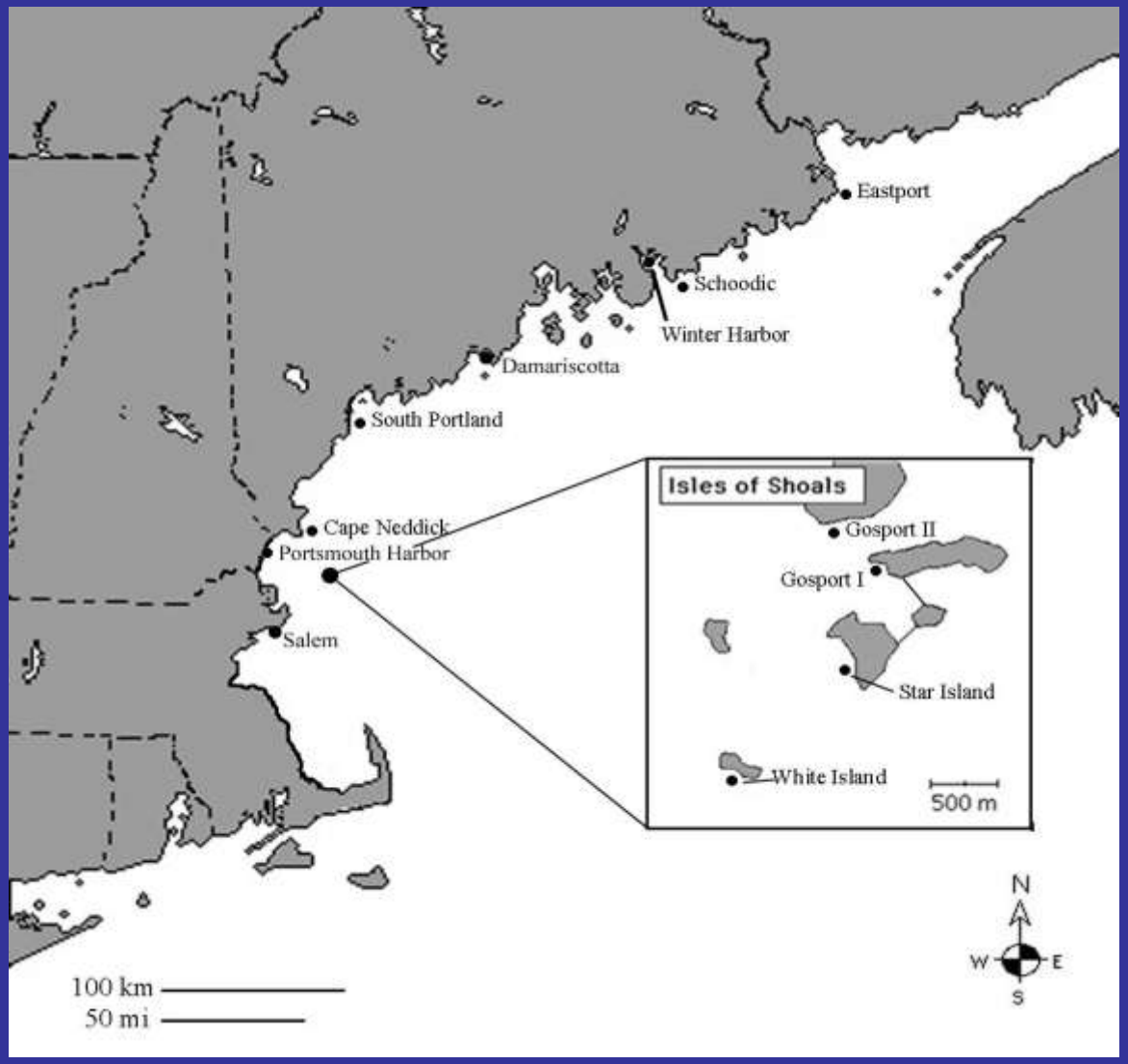
OUTLINE

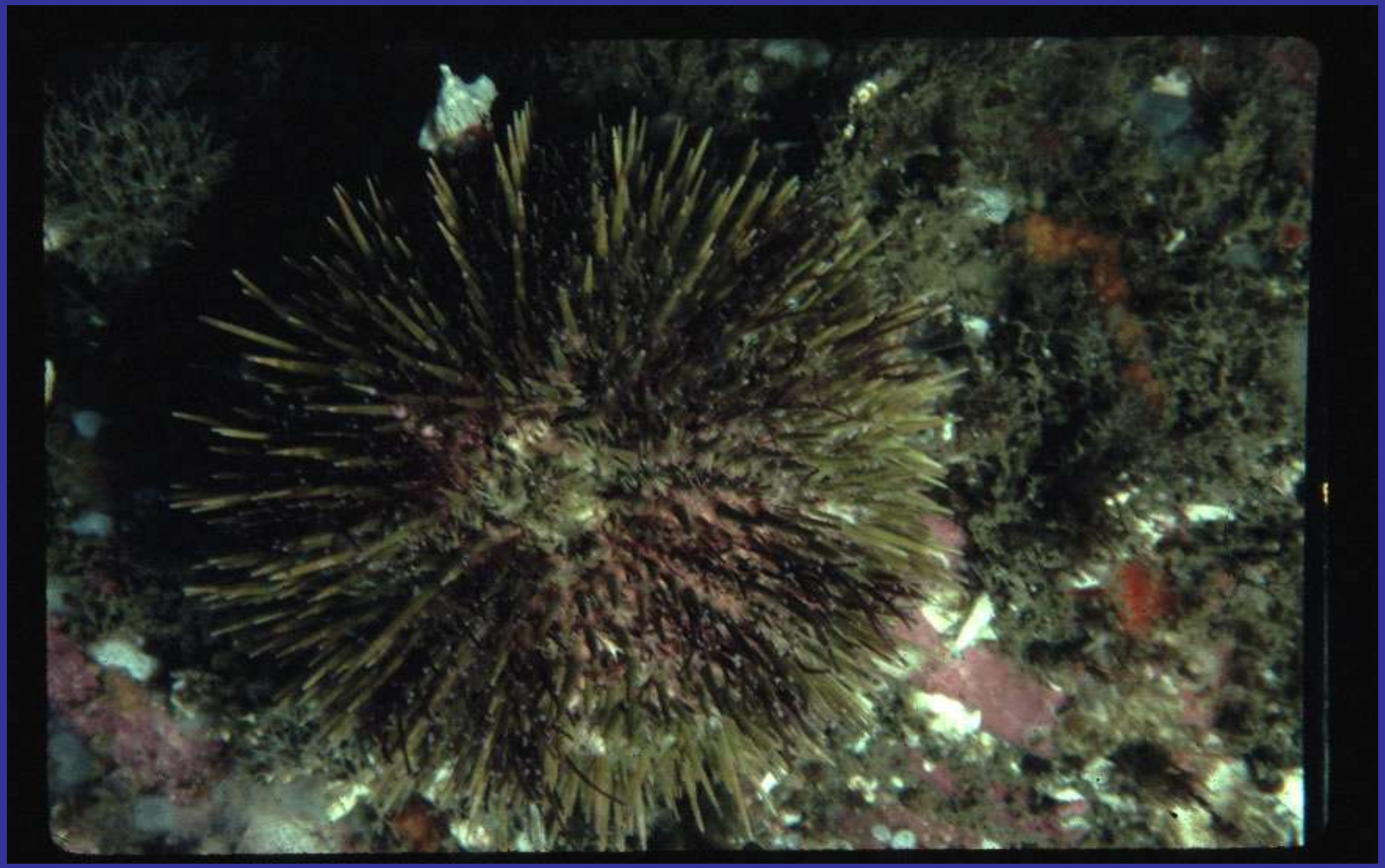
- Description and perspectives on major changes in community state 1970 - 2010
- Invasives present
- Perspectives from two significant examples
- Final thoughts

Map of Gulf of Maine



Historical climax community in GOM – Kelp bed

Strongylocentrotus droebachiensis



PRIMARY LARGE HERBIVORE

- PRIOR TO 1980 - A CRYPTIC SPECIES FEEDING ON DRIFT ALGAE
- POPULATIONS INCREASING, BUT NOT STUDIED
- IN 1980, POPULATIONS BEGAN CONVERTING KELP BED COMMUNITIES TO URCHIN BARRENS

Urchin Front

Urchin Barrens – Star Island 1980 to 1995

EASTPORT, ME – 1970 - 2010

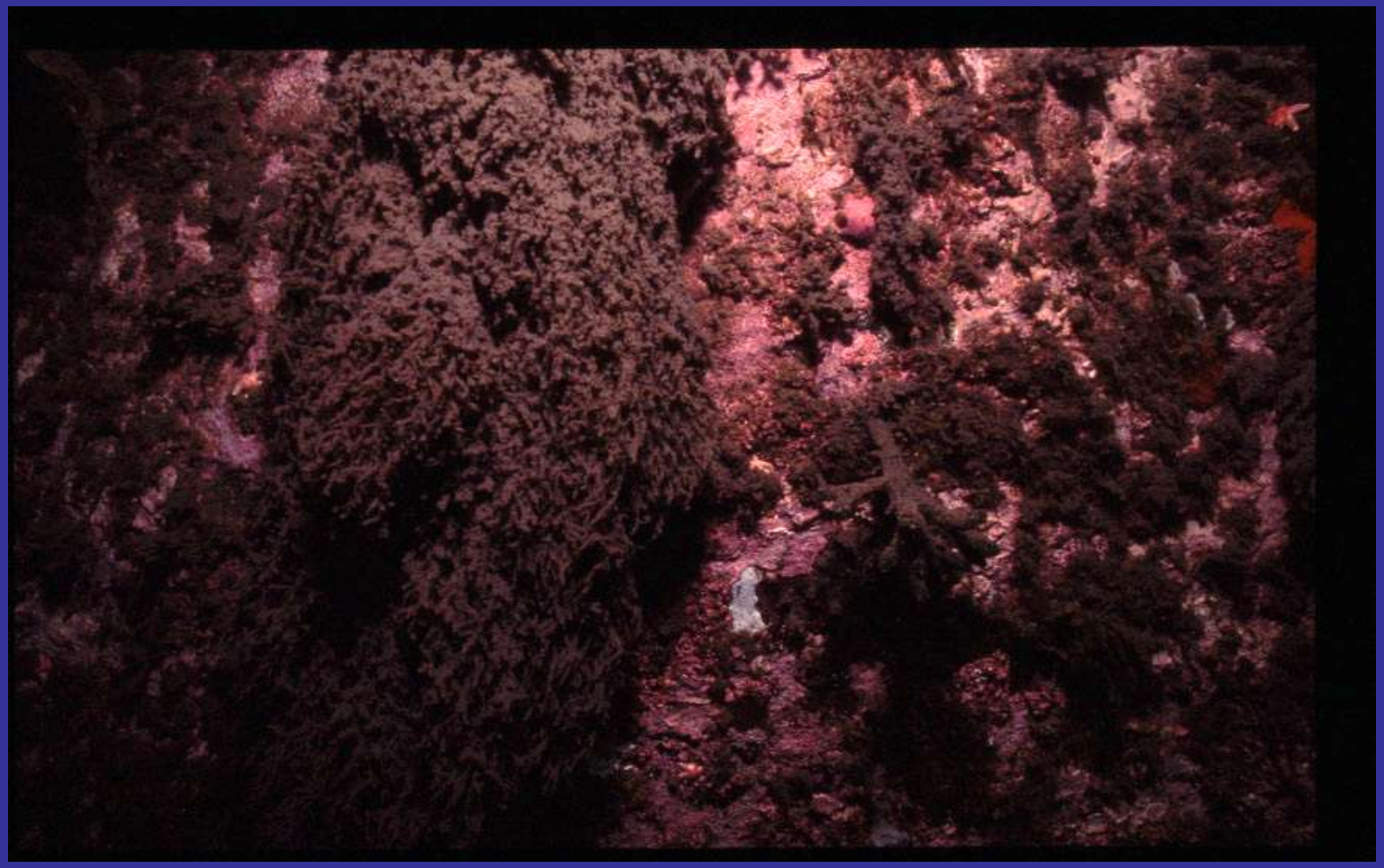
Urchin Harvesting

URCHIN FISHERY CREATES A VACUUM

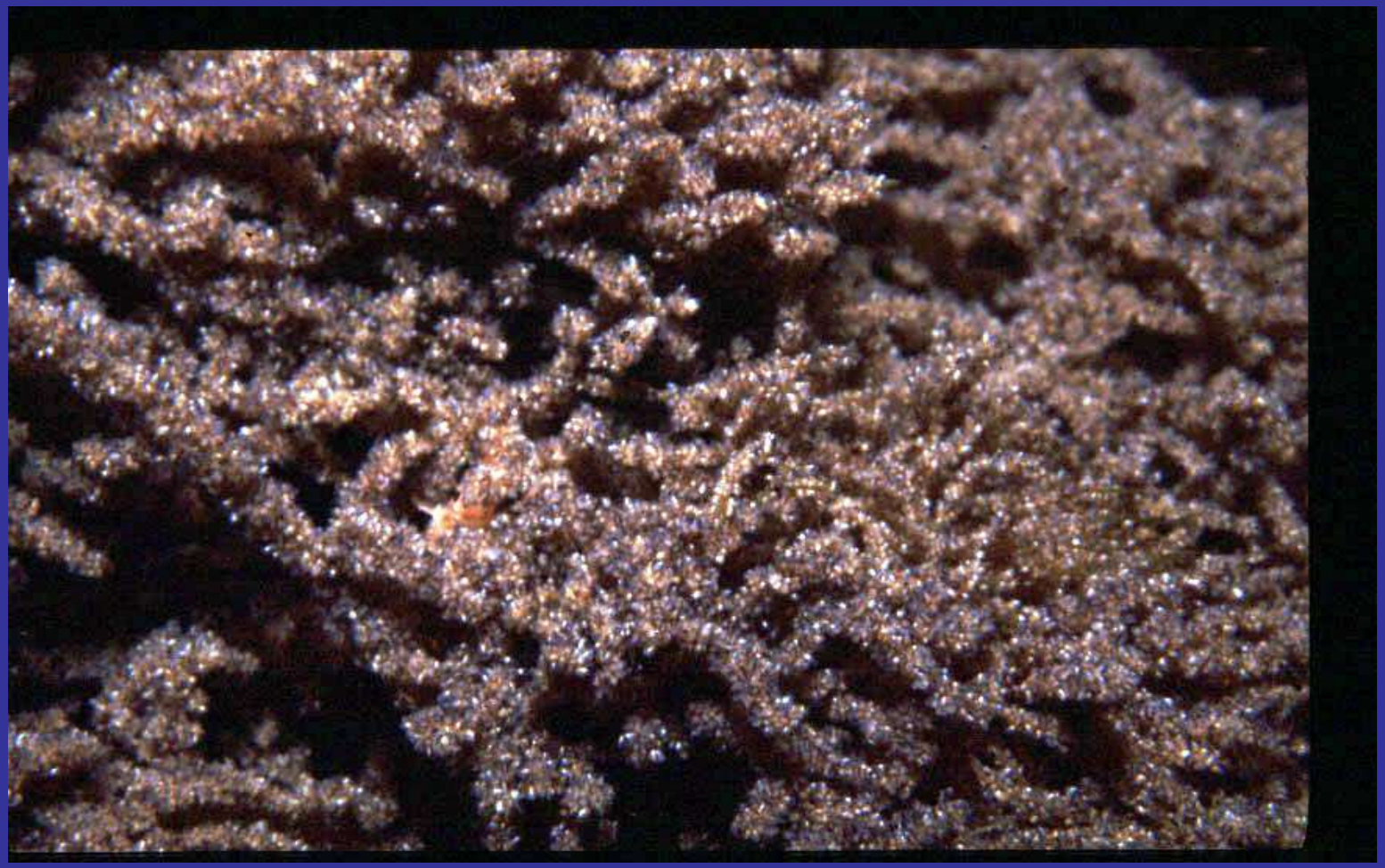
- FISHERY BEGAN IN 1987 AND PEAKED IN 1993 AND HAS BEEN IN DECLINE RECENTLY, WITH SOME INDICATIONS OF SLOW RECOVERY.
- REMOVAL OF URCHINS OPENED SPACE FOR INVASIVE AND OPPORTUNISTIC SPECIES.
- PREDATORS RESPONDED TO THE ABUNDANCE AND INCREASED TOO.

Neosiphonia harveyi – from Asia – Isles of Shoals 1995

Mytilus recruitment

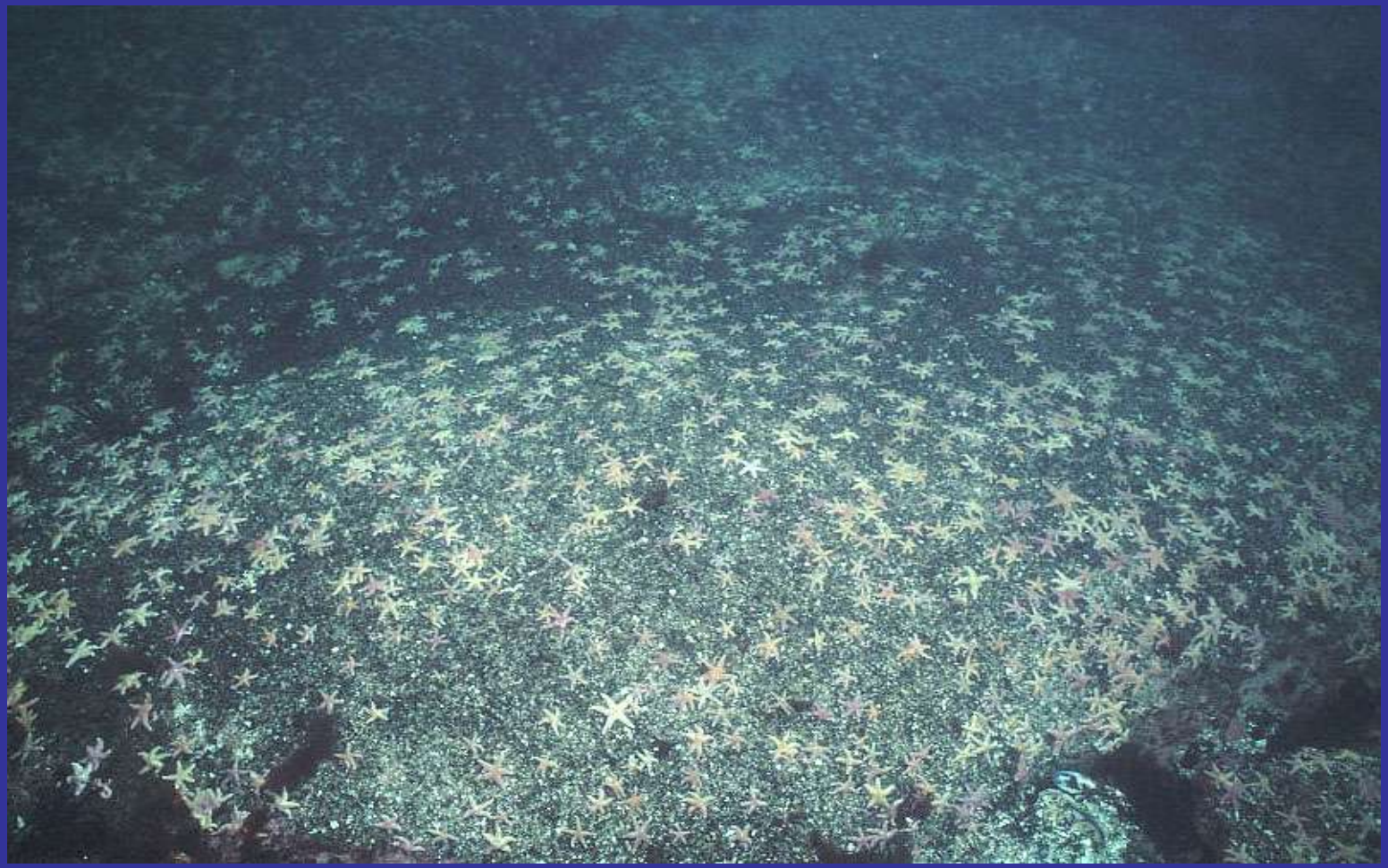


Mytilus spat



Mytilus by the hectare

Milky Way - *Asterias* spp.



Initial pattern after overharvesting of urchins – ephemeral algae supports recruitment of *Mytilus* followed by *Asterias* predation. Mussels removed, sea stars disperse and algae returns and then *Mytilus*.

2005 and 1981

Botrylloides violaceus

Present Community: summer 2005

Historical Community: summer 1981

Mytilus edulis

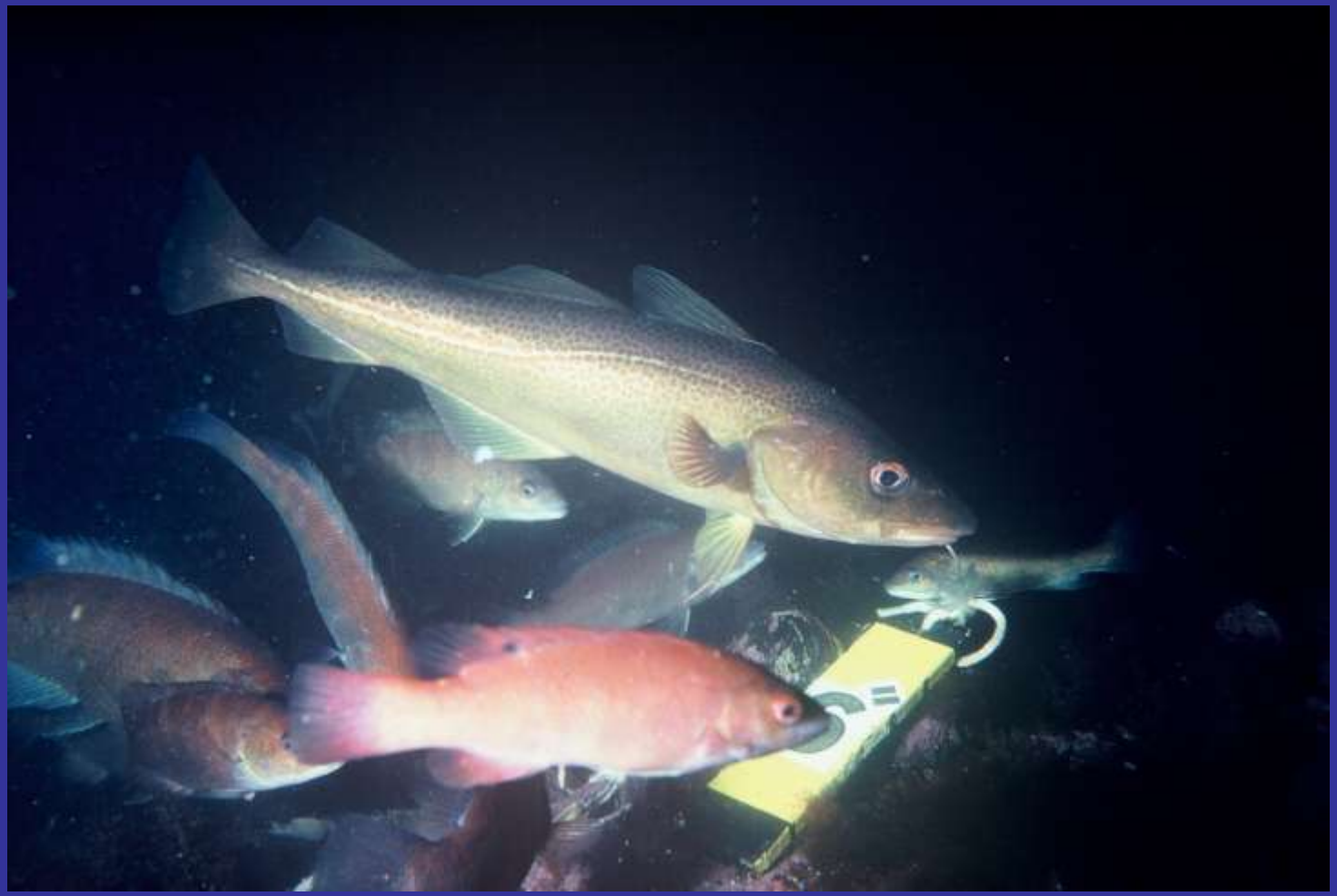
Haliclona sp.

Didemnum at Wentworth Marina, Nov. 2007 - What is wrong with this picture? No *Mytilus*!

SINCE 2005, MUSSEL RECRUITMENT HAS DECLINED SHARPLY

- INCREASED PREDATION?
- INCREASED COMPETITION FROM INVASIVE TUNICATES?
- NEW HYPOTHESIS - INCREASED LARVAL MORTALITY DUE TO INCREASES IN CO_2 CONCENTRATIONS AND LOWER $CACO_3$ CONCENTRATIONS?
- LIKELY THAT ALL THREE PLAY A ROLE.

Cod – a Ghost of abundance past – last seen in the late 1970's



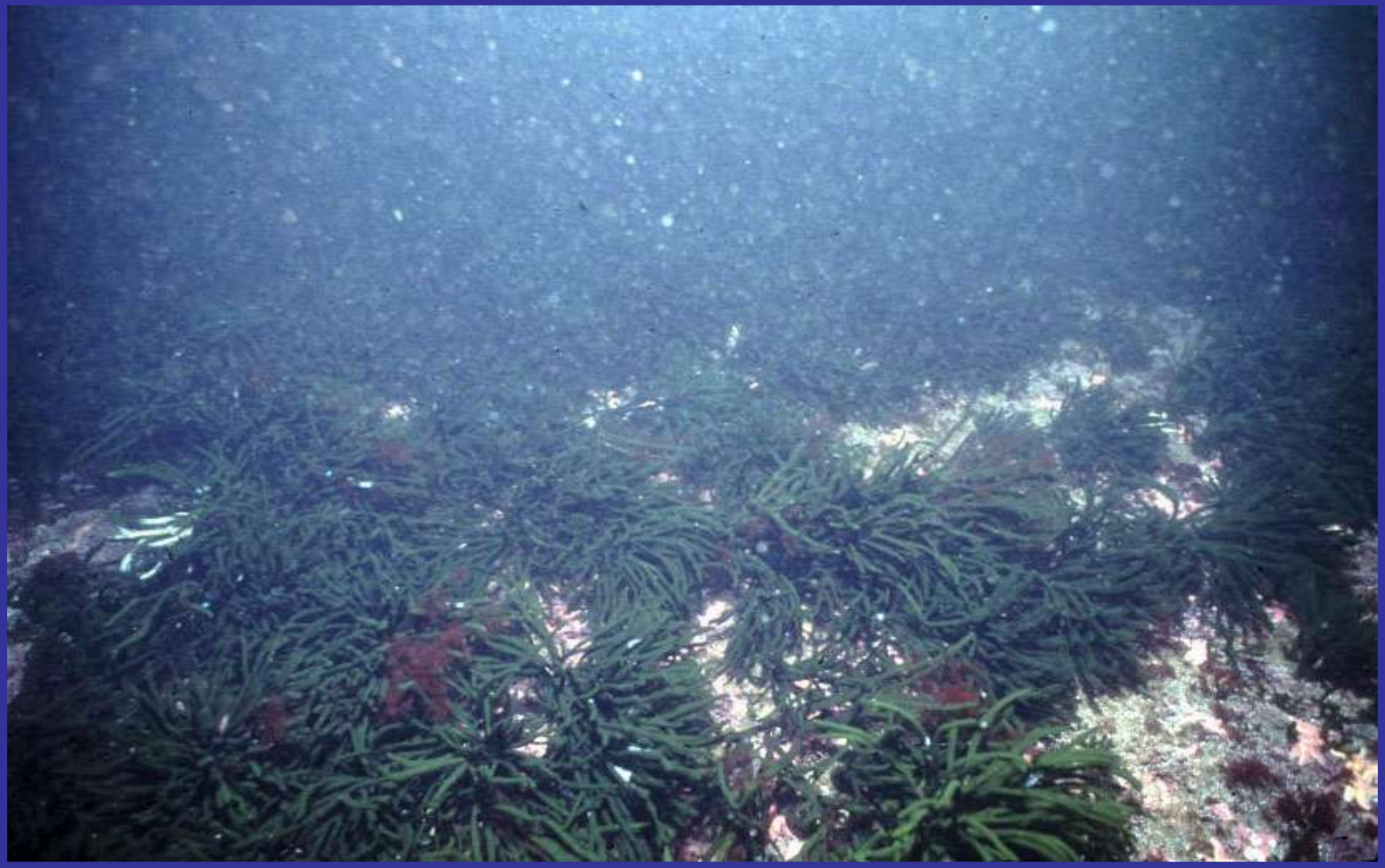
Cancer borealis – the second predator

Heavy recruitment of *Cancer borealis* in 1998 lead to densities of about one adult crab/m2 from 2000 – 2005. No urchins survived this predation intensity.

Tautogolabrus adspersus – the third predator

Tautogolabrus are rare in urchin barrens with no algal cover to recruit to, but populations rebounded with increasing algal cover.

Codium fragile ssp. fragile – the new canopy species.



Codium fragile ssp. *fragile*

- First observed in GOM in Boothbay Harbor and studied.
- Appeared at Isles of Shoals in 1982 and established in protected areas in 1983.
- Began to spread to exposed areas as urchins were removed in mid 1990's.
- Became dominant canopy species for about 5 years.

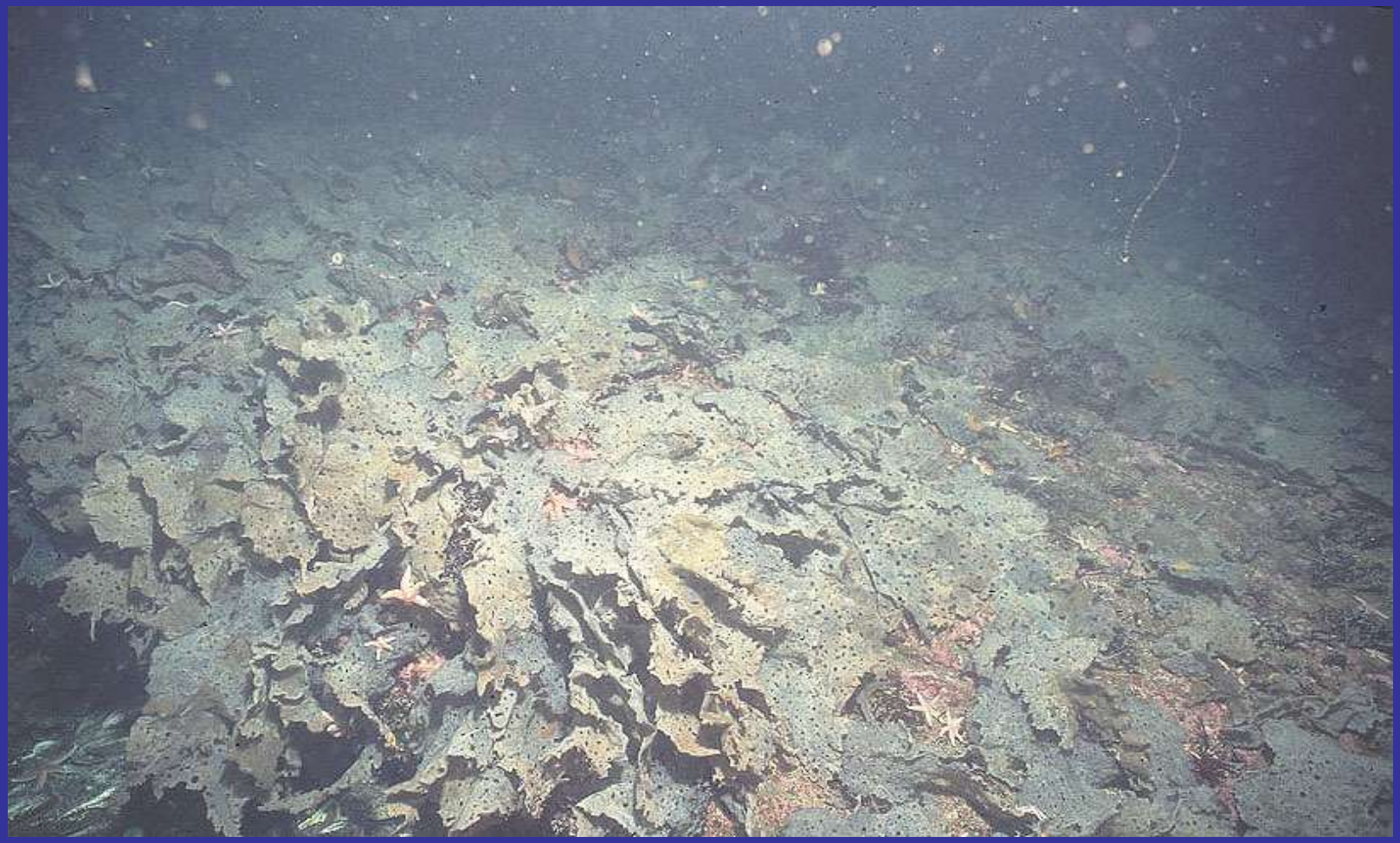
Placida dendritica – specialist herbivore on *Codium*

Placida impact on *Codium*

- *Placida* was present prior to *Codium* introduction, feeding on *Bryopsis*.
- Populations on *Codium* built up over time and primarily in protected areas.
- *Codium* populations that first colonized protected areas now dominate in exposed habitats where the snail does not hold on well in surge - a refuge from predation.

Bonnemaisonia hamifera – a significant space competitor from Asia

Membranipora membranacea



Membranipora membranacea first appeared at Isles of Shoals in 1987 and quickly spread throughout the GOM. Overgrew kelps to impact growth and survival. By 1995 observed kelps altering growth to avoid total overgrowth and then removing over winter.

Onchidoris muricata

A NEW PREY SOURCE FOR *ONCHIDORIS*

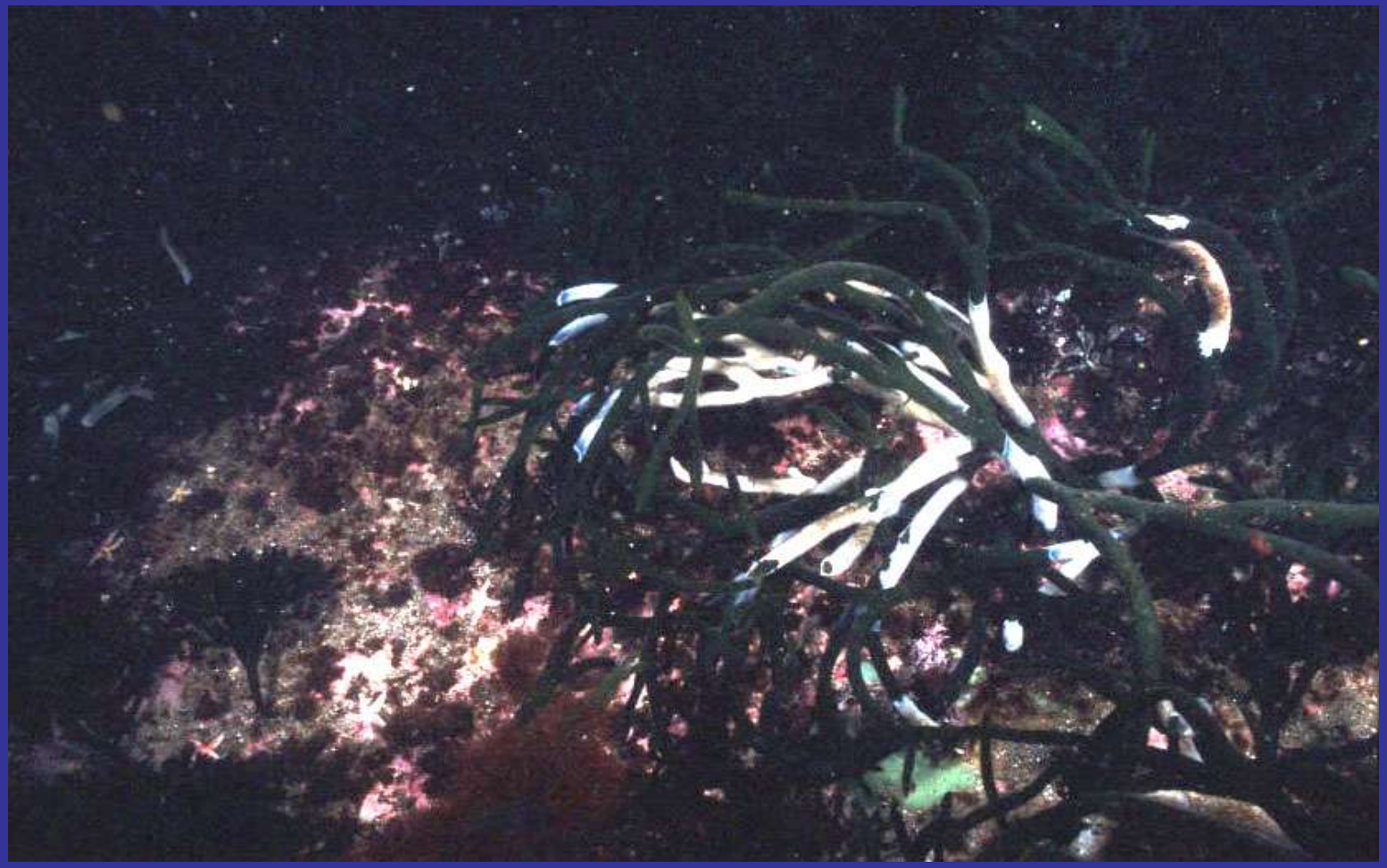
- *Membranipora* appeared in 1987 and *Onchidoris* fed on other bryozoans.
- At first, only adult *Onchidoris* were found on *Membranipora* in the spring at the end of their annual population cycle.
- About 1995, small *Onchidoris* were found on *Membranipora* in the fall.
- Now *Onchidoris* breeds year around.

Habitat Shift – expanded to occupy algae that do not remove colonies in the winter.

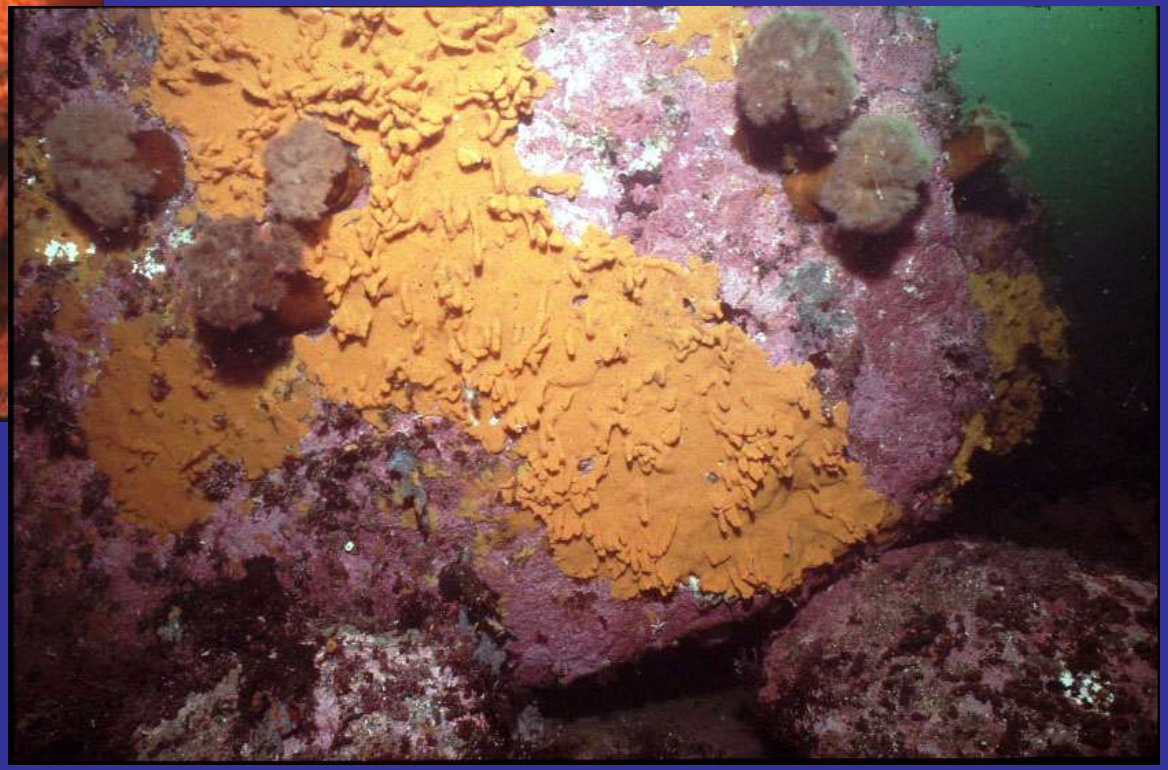
HABITAT SHIFT FOR *MEMBRANIPORA*

- Initially, *Membranipora* was confined to flat bladed algae and kelps in particular.
- Kelps adapted by growing earlier to avoid total coverage by *Membranipora* that blocked blade growth.
- Winter growth by kelps when *Membranipora* is not growing results in colony loss off the abraded end of the blade.
- Winter survival on arborescent algae is higher, so there has been a shift and *Codium* is abundant.

Membranipora on *Codium*



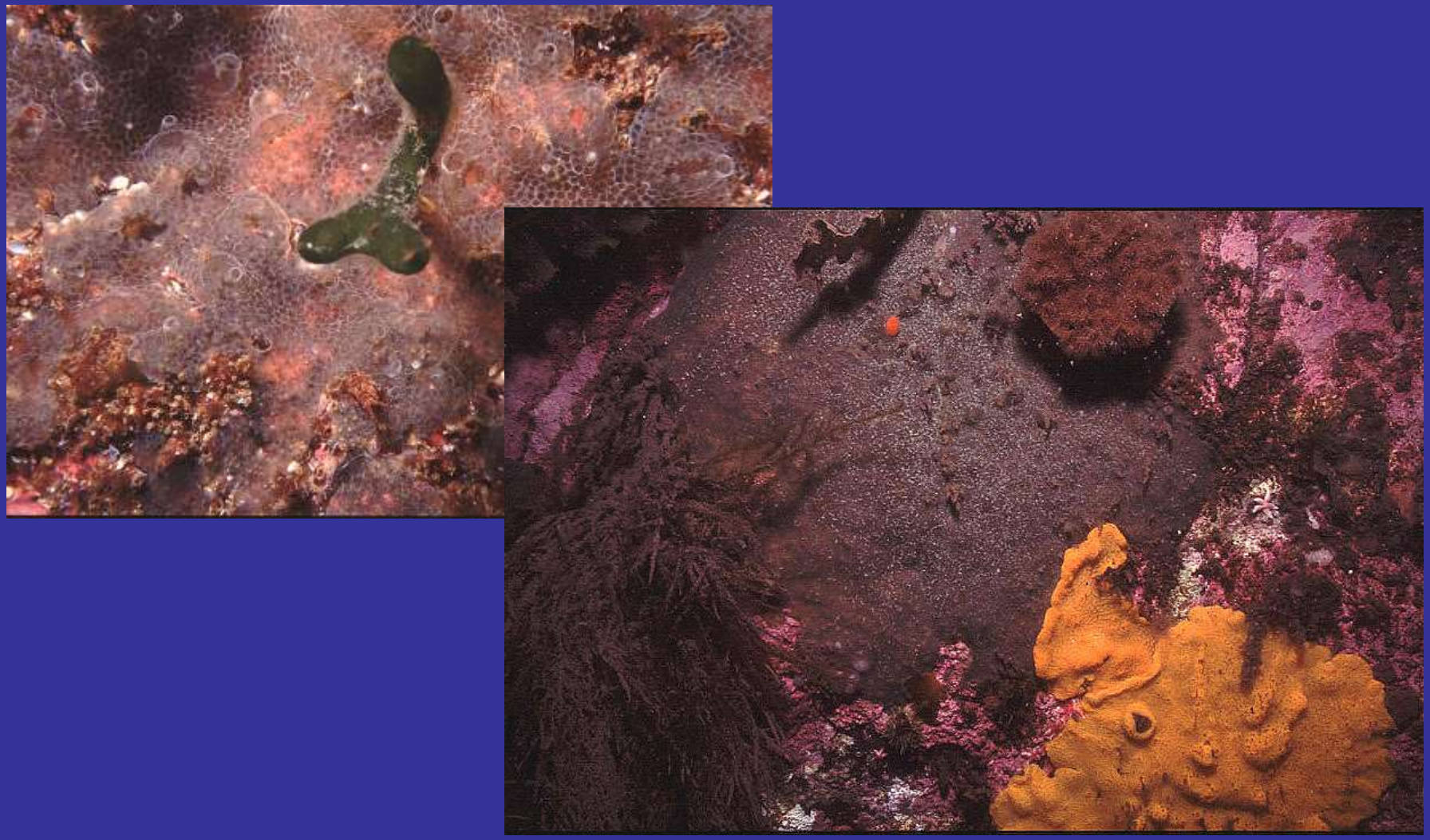
Botrylloides violaceus



Botrylloides violaceus

- First observed in New Hampshire in 1980.
- Rapidly spread and is now dominant intertidal and subtidal colonial tunicate in southern Gulf of Maine.
- Now know that it was present in Damariscotta Estuary in the 1970's.
- It is from Asia and Japanese oyster introductions are a likely vector.

Diplosoma listerianum



Henricia eating *Diplosoma*

Diplosoma listerianum

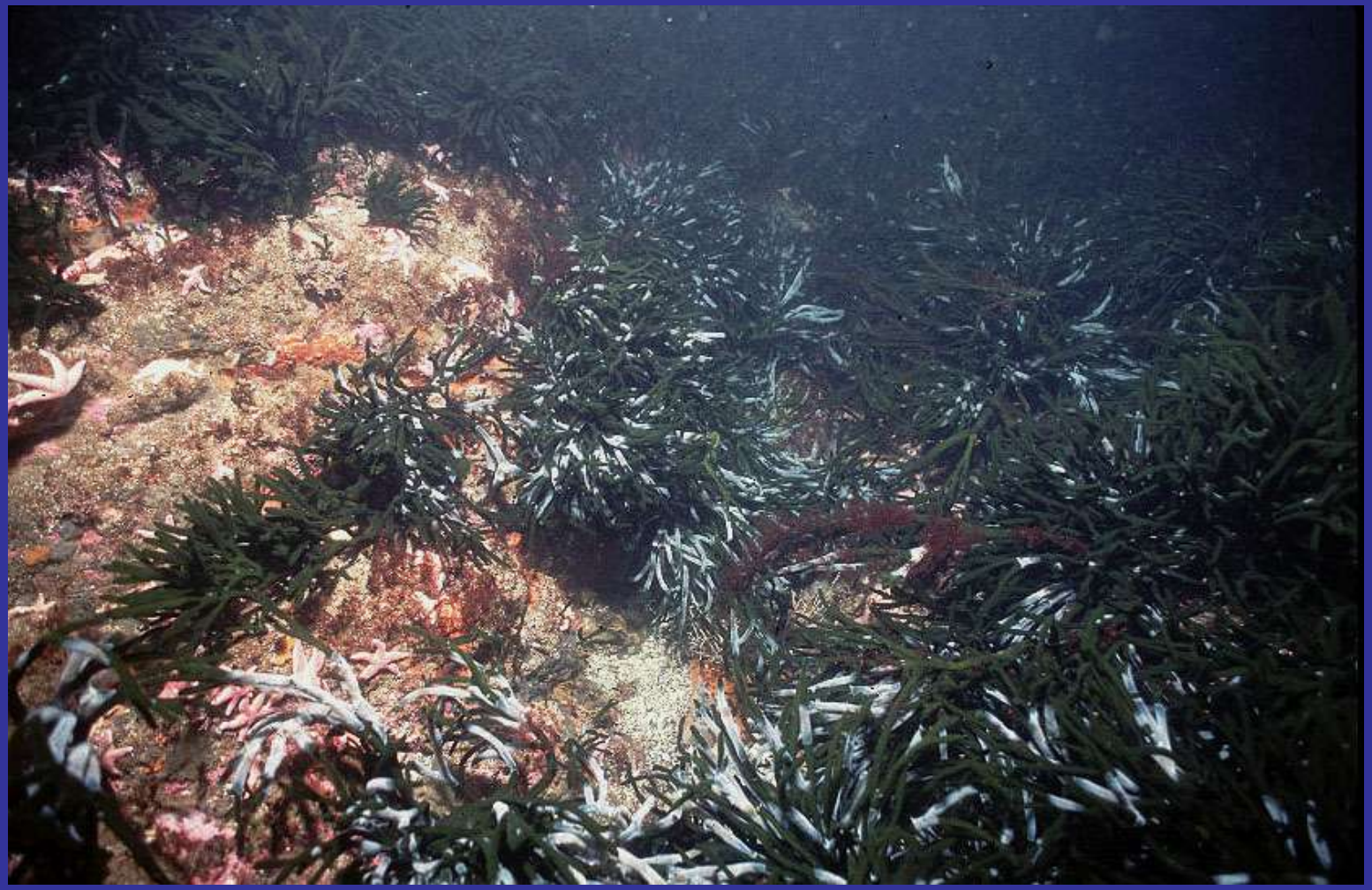
- First observed in New Hampshire waters in 1993.
- Previously known from more southern waters and originally from Europe.
- In September, 1995 a few small colonies were observed at an exposed site.
- Six weeks later, it covered up to 80% of all surfaces.
- Very emphemeral species that does best after mild winters.

Didemnum vexillum - the tunicate from Hell (2005 130+km2 on Georges Bank)

PERSPECTIVES ON TWO SPECIES

-*Codium fragile ssp. fragile*
Asia
-*Didemnum vexillum*
Asia

Codium fragile ssp. fragile



Covered with *Membranipora,* a *Codium* canopy is more complex than a kelp canopy due to the dense bushy growth form. *Codium* supports a much more diverse epibiont community than *Laminaria* spp.

In early summer, 2006 returned after two years to find domination by kelps and little *Codium*.

MAY, 2007

SACCHARINA SENESCENCE – A NATURAL CYCLE

October, 2009 – the cycle repeats

Drag forces from storms remove large *Codium* plants and open space for newly aggressive *Saccharina* to return. *Saccharina* populations undergo a two year cycle of recruitment, growth and senescence after reproduction. Therefore, the canopy component of "kelp beds" is not perennial. **And two colonial tunicates are competing for space historically occupied by algae.**

Study from Korea may indicate future role of *Codium*

- Chavanich et al found that *Codium* in areas of intensive sea weed harvest was the primary canopy species.
- In Marine Reserves where harvesting was not allowed, *Codium* occupied the position of an understory species.
- It appears that *Codium* is becoming a subcanopy species in a new kelp bed community state.

Codium in Maine

- 1964 Boothbay Harbor on oysters
- 1983 Isles of Shoals protected habitats
- 1990 Isles of Shoals exposed habitats
- 1995-present: Dominant canopy species at the Isles of Shoals and increasing in abundance in Maine locations to Boothbay Harbor
- Cape Neddick progression - 2000 (0.1/m2), 2001 (1.3/m2), 2002 (4/m2), 2003 (10/m2), 2004 not sampled (hips), 2005 (23/m2), 2006 (40/m2), 2008 (18/m2 – range 2 to 53/m2).

Didemnum vexillum – FROM ASIA AND FIRST SEEN IN 2000

A significant growing presence!

- 2000 “Discovered” Cape Cod region on Rapid Assessment Survey
- 2001 Portsmouth Harbor
  - Presentation on invasive species to Metro West Dive Club. “No, it is not new. Present in Mass Bay for several years”.
- 2003
  - B. McInnis- Eastport at least four years
  - R. Wahle- Darling Marine Center 1994
  - P. Valentine- Significant populations on Georges Bank
  - P. Yund- Damariscotta Estuary 1988
- 2004- R. Cline- “ The photos look like our old friend we suspension oyster growers in the 1970’s and early 80’s called tan sh…”

Lantern nets on the Damariscotta, 1982

Half Moon Cove, Eastport - 2005

Commercial Wharf – Eastport 2006

Didemnum on every wharf piling

ADDITIONAL ASCIDIANS

- There are a series of tunicates that are established and have the potential to become problems or are already invasive.
- As tunicates become more prevalent in both benthic and fouling communities, mussels, anemones and sponges appear to be declining in their roles in these communities.

Botryllus schlosseri

Botryllus schlosseri

- Reported as present in 1870 by Gould
- Likely of Pacific origin
- Common on vertical surfaces and as an epibiont
- Limited in size, but most tolerant of low salinity and survives very low temperatures

Ciona intestinalis

Ciona intestinalis

- Reported as common in 1940 by Minor, but probably of European origin
- Very cold tolerant, but sensitive to low salinities
- Rapid growth and large size, but preyed upon by snails, crabs and wrasses, so limited to refuge habitats (= suspended docks and aquaculture structures)

Styela clava

Styela clava

- Moving north in Gulf of Maine from south of Cape Cod, but of Asian origin
- Currently present to Penobscot Bay
- Large size and competitive with mussels and anemones and a substrate for many epibionts
- Sensitive to low salinities
- May be losing in competition with colonial tunicates

Ascidiella adspersa

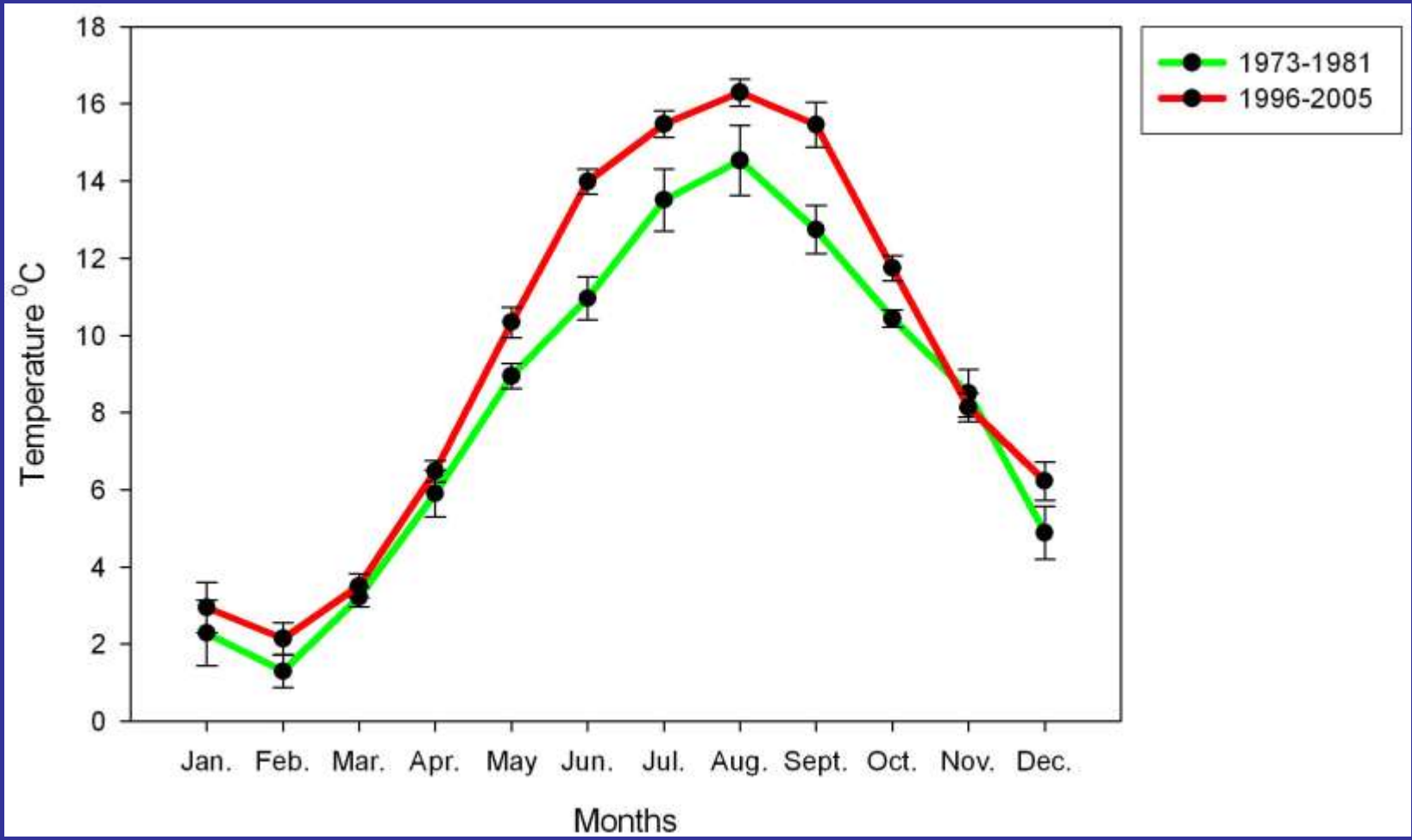
Ascidiella adspersa

- First seen on floats in Salem Harbor in 1980's
- It is from Europe
- Limited populations now into Casco Bay
- As large as *Ciona*, but more sensitive to cold and not as aggressive
- Very sensitive to low salinity

IMPLICATIONS FOR THE FUTURE

- WATER TEMPERATURES ARE INCREASING, WHICH FAVORS INTRODUCED SPECIES TO THE DETRIMENT OF NATIVE SPECIES.
- THERE ARE SPECIES TO THE SOUTH THAT ARE MOVING NORTH AND ARE LIKELY TO APPEAR IN CASCO BAY WITH IMPACTS THAT ARE YET TO BE DETERMINED.

Mean Monthly Temperatures - Portsmouth Harbor - 25 Years



THE DAMARISCOTTA ESTUARY WAS THE SITE OF EXTENSIVE BIVALVE AQUACULTURE RESEARCH INCLUDING UTILIZING THE EUROPEAN OYSTER *OSTREA EDULIS* AND THE JAPANESE OYSTER *CRASSOSTREA GIGAS* - (*CODIUM, BOTYRLLOIDES* AND *DIDEMNUM* ARE FROM ASIA)

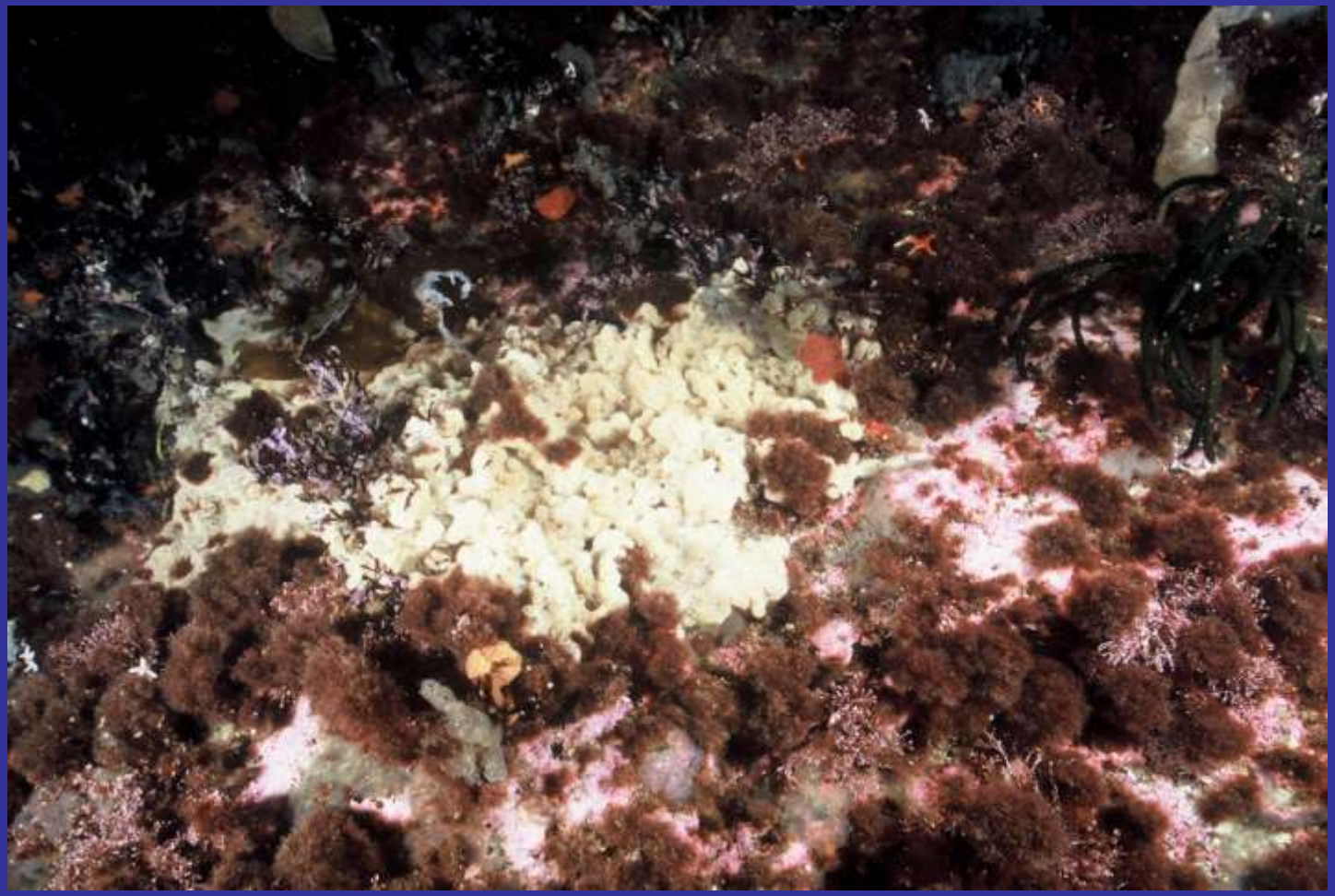
Codium and *Didemnum*: Two successful invasive species

1. Introduced with oyster aquaculture
2. Limited distribution while adapting to GOM
3. Once adapted, both species rapidly expanded their range.
4. Once established and expanding, a species is a different beast and the potential for control is poor and impact great.
5. Awareness and monitoring may allow mitigation during the early adaptive phase of an invasive species

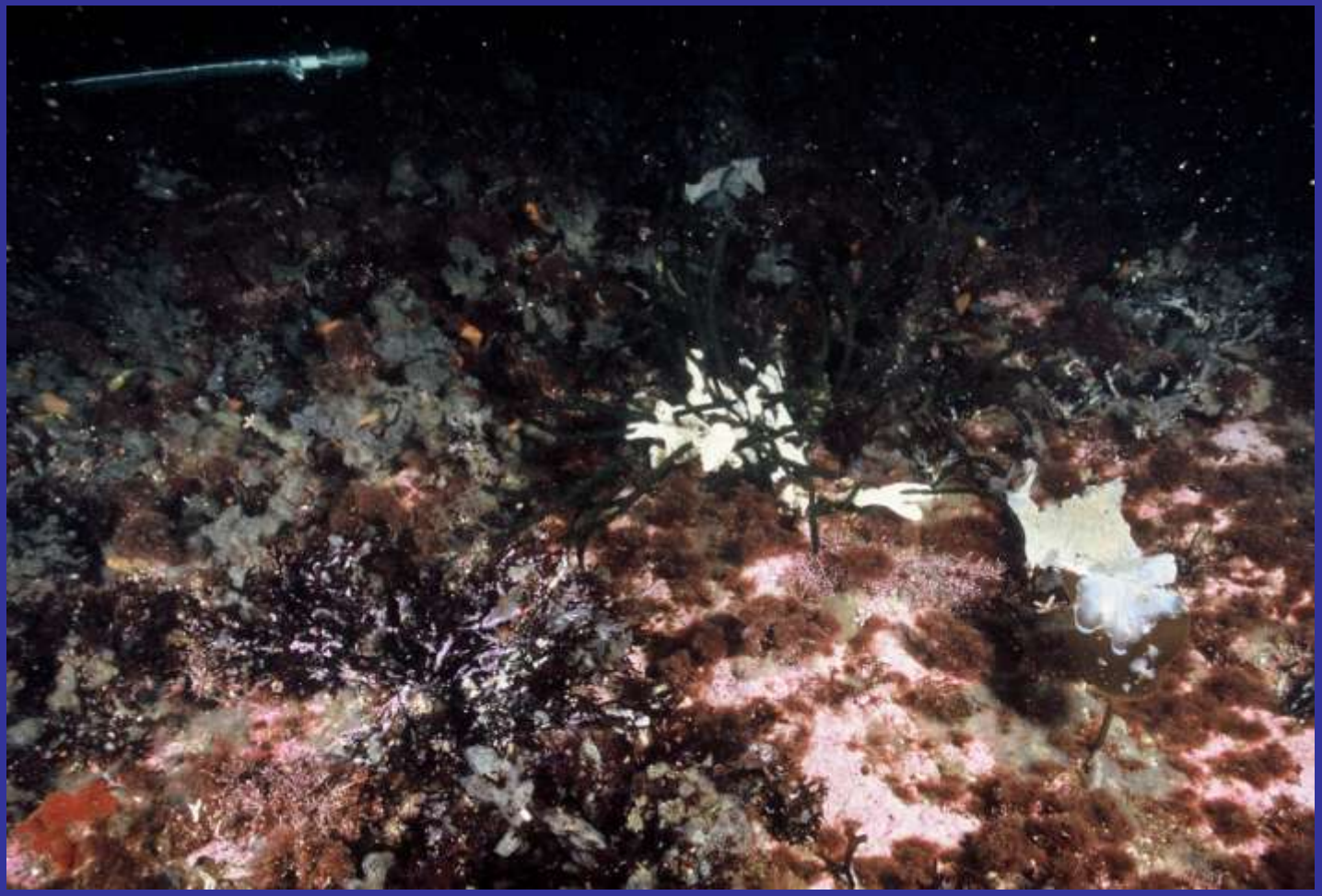
OBSERVATIONS

- MANY SPECIES WERE PRESENT BUT NOT A PROBLEM FOR A TIME BEFORE THEY BECAME INVASIVE
- MANY INVASIVE SPECIES ATTRACT PREDATORS AFTER THEY ARE PRESENT FOR AWHILE
- THE INCREASE IN PREDATORS MAY HAVE AN IMPACT ON ENDEMIC PREY ALSO
- BOTH INVASIVE AND ENDEMIC SPECIES ADAPT TO THE NEW CONDITIONS SO THE COMMUNITIES AND SPECIES WE STUDY ARE NEW

New Benthic Community State – 6 of 10 dominant species are introduced



Ecosystem Services?



FINAL THOUGHTS

- WE ARE WATCHING EVOLUTION TAKE PLACE.
- THE GULF OF MAINE IS A LOW DIVERSITY SYSTEM WITH HIGH ABIOTIC VARIATION WHERE BEING A GENERALIST IS AN ADVANTAGE.
- GENERALISTS ARE ABLE TO ADAPT TO NEW SELECTIVE FORCES AND WE ARE OBSERVING THE DEVELOPMENT OF A NEW COMMUNITY STATE STILL IN A STATE OF FLUX.

FINAL QUESTION

- HOW DO YOU DETERMINE ECOSYSTEM SERVICES AS WELL AS MANAGE OR RESTORE AN ECOSYSTEM IN WHICH THE BASELINE IS STILL SLIDING TOWARD AN END STATE THAT HAS NO PRECENDENT?