CORONA 2003, Reykjavík, Iceland

Monday August 11th

Cliff Cunningham- Let's start with the assembly of the Icelandic community. Across the North Atlantic we have various communities… After lunch – we'll break into workshops and small groups

Agnar Ingólfsson– Composition and origin of shallow-water Icelandic marine fauna

There are no endemics in Iceland! Not in marine waters, anyway. Some in freshwater. No populations that are distinguishable from Europe and North America, so recent in Iceland. Can't distinguish any populations. The marine fauna is distinctly European. Intertidal macrofauna of Iceland – about 150 species that are reasonably well known. The majority are amphi-Atlantic, occur in Europe and North America – about 80% of the remaining species are all European. Some data for three groups – echinoderms, prosobranch gastropods and bivalves in Icelandic waters – Einarsson 1948, Thorson 1941, Madsen 1949 – data are old. 269 spp, 170 amphi-Atlantic, 96 European, 3 American spp, all small and distribution was imperfectly known at that time, I don't know situation now.

Cliff – names of those species?
Agnar – I don't know; one echinoderm, one gastropod and one bivalve
Traffic through Iceland was west from Europe, to east from North America. Looking at morphological spp; genetic data may show something else – we will hear about this later on. Look at species distribution in Iceland, North America and Europe, and one can delimit areas that are more similar to Iceland – Canadian maritimes and Lofoten islands to Russian border. I like to use the term the Icelandic zone. No coincidence that average temps are about the same – 5 degree mean annual isotherm (Celsius). Icelandic fauna is clearly a subset of that of northern Norway. A large subset if you look at the rocky shore species - about 95 % of the northern Norwegian species are found in Iceland; most have made it to Iceland, a few have not; the rocky shore fauna from North America is a subset of that from Iceland. It's a larger subset of Iceland, a somewhat smaller subset of those from Norway; the question is how on earth did the species make it? Very difficult to see how they traveled all this way, at least for most of the species. There are some possibilities – survival during the glacial periods is a possibility and no migration, but that only puts the problem back in time; so not a solution to my mind; some swimming, could some have crawled along the Iceland-Faroes ridge? Maybe a possibility for species that can go relatively deep – we'll hear more about this; then there is rafting; pelagic larvae are only a possibility in a minority of cases; the majority of the shallow water marine fauna have pelagic larvae, but are very short lived - can't make the travel to Iceland. Rafting is the best possibility in my mind – several types of rafts – ice (improbable, few species associated with ice), driftwood (I think we lack the data on this - I think the data is all from the tropics not temperate areas) ; algal mats – best guess here; lots of floating algae around here; far away from continents; *Ascophyllum* can survive for months floating out in the ocean; algal mats are dependent on the winds rather than on the

currents – a few weeks of very strong easterly winds can drive the mat in a few weeks from Norway to Iceland, while it would take years by the currents; here in Iceland we have a few good examples of what are probably introductions; *Mya arenaria*, another bivalve, *Orchestia gammarellus*; I'm sure I'm long past my ten minutes…
Geerat Vermeij – in the past __ years, ? has described quite a few Iceland endemic deepwater forms. Is there more endemism in the deep water or is this an artifact of collecting?
Agnar – I don't really know, but probably an artifact of collecting; very unlikely to my mind that there are any endemics to Iceland.
Snaebjorn Palsson– collecting from the trawl, those things that can be collected in the trawl; strange things stuck in the nets; I think this is an artifact
Agnar – *Stichotera cubensis*, *Asymella cubensis*, *Tenuis*(???)
Geerat – the *Tenuis* was recently recognized as being in Europe; the *Trichotropus*?
Hal Borns – Univ. of Maine – I did not do my homework on Iceland before I came, any post-glacial emerged marine deposits? When did the present fauna arrive? Is there late-glacial uplift of deposits, if you lift weight of ice, where you can access it?
Agnar – Can I direct this to the geologists?
Hal – Another question – do the fauna of today show up in what are the middens that the early settlers in their garbage dumps on the coastal farms – do they have the remains of the present fauna as well as a thousand years ago?
Agnar – not to my knowledge –
Geerat – *Mytilus* is in the middens
Jon Witman – what about the southern tip of Greenland? Is that part of the Icelandic zone, or biogeographically distinct?
Agnar – mixture of nearctic and palearctic species - more nearctic and fewer paleartic species than Iceland; Atlantic is much cooler – Greenland goes much farther north of Iceland
Steve Hawkins – Of the Norwegian fauna that has made its way to Iceland, which can be described as trans-Arctic species, and which could have worked their way north from say an African refugium? Would that be an interesting question to look at?
Agnar – There's nothing in Iceland that isn't from Norway
Steve – But which ones are from the Pacific and which are from southern Atlantic origin, can we get a handle on that?
Geerat – All of the Pacific species that are in Europe today are also on the Atlantic side of America today, and are in Iceland, except for a few – eg. *Littorina littorea* which is not in Iceland … otherwise, I don't know that anybody knows, but data should be easily obtainable; there are some species that are found…
Wares – Isn't there are a strong cline on the Iberian peninsula?… [missed the rest of this]
Vermeij – But an awful lot do – lots of species that go down to Morocco reach to northern Norway and also Iceland
Cliff – We should revisit this, come up with catalogs of organismal groups, characteristics that characterize eastern Atlantic, trans-Arctic
Howie Spero – I think when you look at this map, something to keep in mind is the polar front went down to Portugal. Migration over from Portugal to North Atlantic; source for northern Europe. About ice rafts – huge cleaving glaciers – any evidence of organisms

being transported by icebergs rather than sea ice? Also driven by wind not by currents? Just a suggestion, what about the Southern Ocean?
Geerat and Agnar – No evidence.
Ladd Johnson – talk about complete exchange between northern Norway and Iceland, what is the potential pool in North America that could have gotten there?
Agnar – Quite a large pool of American species that you find in the maritimes that I would imagine could make it here in Iceland, but none of them made it.
Ladd – tens, hundreds?
Agnar- macro, meio fauna? At least several tens, dozens of species

Karl Gunnarsson –A brief introduction to the seaweed fauna of Iceland. About 250 species, 70 green, 79 brown, rest red algae. I expect actual number is a bit more; we're constantly discovering new spp; in a survey we do. For comparison I will say in Britain and Ireland there are about 650 species Norway 470, 240 north of Lofoten; 260 are in Faroes; 180 species in Greenland, a little more than 300 species in eastern Canada; temperature gradient from southwest going clockwise around country, warmest in south, gets warmer as you go around; temp fluctuation is greatest in west; in east fluctuation is less; the south coast is mostly exposed shores and black volcanic sand; north – rocky coasts, gravel and sediment. The tidal level is highest in the west – up to six meters at spring tide, north and east tidal amplitude is much less. The vegetation on the rocky coasts - fucoids, with about six species dominating different levels of the shore; two, *Fucus serratus* and *Pelvetia* are only found in the southwest; all the others are found mostly along the coast, except sandy banks of southern part. There are six species of *Laminaria*, they dominate different areas/environments; often down to more than 25 m depth. Fergusson they are classified in five categories from boreal to arctic, all groups are present in Icelandic flora; arctic and subarctic groups are best represented, but all are found in Iceland. There are about 80 species that have northern limit in Iceland, about ten with southern limit in Iceland; marked differences in species composition between west and east coasts, the east coast flora is more arctic; many European species reached Iceland and didn't go further west, there's only one North American species that reached Iceland and didn't go further east. I will try to address dispersal after last glacial maximum like Agnar using seaweeds instead. The flora in eastern Canada and Europe - probable that they crossed from Europe to Canada as glacial maximum covered all the rocky substrate in North America; no habitat for the littoral seaweed. European coast sub-arctic flora moved further south when the glaciers covered most of northern Europe, when the glacier receded the seaweeds probably followed up to northern Norway; what I did was looking at the littoral seaweeds, I selected from 375 species that are found in these three areas; Iceland, northern Norway and eastern Canada; and tried to select all littoral species; no sub-littoral, and also included littoral species that can go down to about 10 m; took out all species different taxonomically; a number of taxonomic problems that I took out that might be apart of the life cycle of other species. I was left with 66 species of algae; subset of 375 species were used in the analysis; for total number of species there is no change from east to the west, but in many cases the species that are lacking in one region are found elsewhere along the coast; for example seven species were missing in northern Norway but found further south; added these in, then all green algae found in all three regions; brown same in Iceland and Canada, three more in

Norway; red algae – three fewer in Canada than Norway, but one fewer than Canada in Iceland, so whether Iceland is stepping stone is not clear from this analysis, but at least some of these species have…..
Cliff – You selected species that already had a trans-Atlantic distribution?
Karl – No, no, they had to be reported in just one of these locations not all of them
Agnar – There are some species that are found in Canada and Norway and not Iceland?
Karl – yes – missed examples; one species is endemic to eastern Canada, but I don't know that taxonomic designation; brown algae found in eastern Canada but not elsewhere;
Geerat –what occurs in Iceland and Canada but not Europe?
Karl - brown crustose – I missed name.

Cliff – I think the pattern is clear, it's just different
Karl – can spread easily and survived in the [missed a bit here]
Malden(??)
Spreading of the spores and propagules has to go against the current, right?
Karl – North Atlantic current goes from west to east, but at the ice edge north of Iceland, the current goes the other way, so when the ice edge was further south, there's indication the current was going the other way;
John – I wonder, if we know that almost all of these macroalgae are found on all these coasts, what is the proportion of the epibiotic spp., the North Atlantic epibionts should have their habitat in North America, so should be less depauperate?
Cliff – One clue - we have genetic evidence for refugia area later, in terms of animals – a number of cases with shared single haplotype across North Atlantic, several cases of this, it seems like sweepstakes sort of dispersal, occasional migrant will make it across, those with crawling larvae seem to have an easier time establishing from small source.
Jeanine Olsen – I don't disagree with that comment form genetic point of view – we do see genetic association between Europe and Iceland; sea grass data – *Zostera* populations on maritimes side, have links with Pacific, consider not just up and down colonization on European coastline, but also consider recolonize in modern sense from top down; so top down and bottom up but not in ecologists' sense.
Cliff – *S. droebachiensis* has also recently colonized.
Jeanine – Rarefaction techniques with *Zostera marina*, slight difference between the two favoring the European side; it's complicated for the…
Tom Cronin – Are we assuming that during the last glacial maximum all habitats that we've been describing, rocky intertidal and shallow sublittoral were eliminated in Iceland because of ice cover or sea level drop? We're assuming that Iceland was de-habitated during the last glacial maximum that all have recolonized in the last 18-20 kya?
Agnar – That was certainly what I was assuming ten years ago, but now I'm having some pretty serious doubts.
Tom – but the glacial geology is known very well, right?
Hal Borns – I believe that he last glacial maximum stood off shore…
Tom – but you also dropped sea level 120 m
Tom – but might have been refugial population distal to the ice margin, unless I'm wrong with the…

Jon Eiriksson – I'll be touching on this in my talk in a few minutes.
Tom – it's a fundamental difference from continual margins where species can go south, and they do, we know they do, but they don't have that in the north…
Jeanine Olsen – one question – has anyone argued that marine flora that's more along the northern Siberian coast; we constantly come down on the Canadian side, what about the Russian side?? Anyone looked in the last hundred years or so?
Karl – not a lot of studying of Siberian flora
Jeanine –further than the White sea
Hal Borns – elevated marine sediments – around 15kya, there's seaweed mixed in; that particular seaweed is extinct in the Americas but extant in Europe? Has anyone looked at fossil sediments from Norway and northern Denmark and North America too? There's a record, but that might shed light on problems of migration, extinction and evolution.
Chris Maggs – Seaweed you're talking about is *Ascophyllum*
Jeanine - also a *Desmarestia* - *Desmarestia ligulata*
Hal Borns – my point is that there isn't all…….
Chris Maggs- what condition are they in? Can you see that they're seaweed?
Hal Borns – of course! …like ribbons of seaweed and broken up shells along old shoreline.

Jörundur Svavarsson – stepping stones – Iceland-Faroes ridge – ridge itself, when you look at this map; there is something interesting, lack of east west coastline, continents are northern southern coastline; when you go below the surface, the deep water is characterized by a deep ridge – mid Atlantic ridge; oceans go down to 4000m, also north e of Iceland, ocean is 4000m deep; only a small ridge crossing from the east to west – Greenland-Iceland-Faroe ridge; very interesting ridge indeed, I would like to raise the question is it a barrier or stepping stone; interesting – separates these Nordic Sea and Atlantic basins; maximum depth 830 m on ridge; that's between Faroes and Scotland and Iceland to Greenland is about 700 m, so fairly shallow ridge; in the midst of the Atlantic ocean; stepping stone or barrier??? Lots of studies in this area, and I would like to present some data on the potential of this ridge as a barrier; I've been mainly working on isopod crustaceans, Bob Hessler (?) has been working on this group. Family Gnathiidae, ten species, known in the waters around Iceland; what we call the BIOICE area, ten species known and what's peculiar are only six are known south of the ridge, no species known north of the ridge, three species both north and south of the ridge; so definitely a lot of things happening here; Anthuridae – another group of isopods, in all 9 species known, of those nine, there are six known south of the ridge, three on both sides of the ridge, and no species north of the ridge; if you look at aquatic amphipods…
Howie Spero – these are all benthic???
Jörundur- all benthic, no pelagic larvae; Calliopiidae, fairly species rich amphipod family, 18 known spp, only 12 north of the ridge, one species south of the ridge, five species are on both sides of the ridge. Eusiridae – 36 known species, of those, 28 are only south of the ridge, four only to the north of the ridge, four both south and north; something is happening at this ridge – in my opinion this is one of the last biogeographic barriers in the world; boundary of temps – cold water north of it, warmer water south of

it; how is this reflected in other things?? My other transparency concerns endemism; the percentage of endemism – at 700-800 m, species live both on north and south (low endemism); once you get deeper – 1000-4000 m, then endemism increases; one of the largest biogeographic barriers in the world; can also be sort of a stepping stone; I have been browsing through the isopod literature, and trying to figure how this is reflected in the distribution of the isopods; but hard time – the knowledge of the areas is so different; in Scandinavia, most of work is old, species need revision, on other hand area around Iceland - lots of recent sampling, so most of species ID's are stable for today; Greenland – a lack of info, Greenland is very much under-sampled. Look at distributions, may see a distribution may have ;……. There are cases among the isopods *Natatoalana(??) borealis* – scavenger from 5m to 700m, species that needed ridge to pass over, common in Faroe Islands, common off Norway and down to England?????? Also in Florida and Carolinas!!

Cliff – Thank you, this is the first look we've had at deep sea broad geographic patterns
Howie- During the ice age with sea ice a lot thicker and sea level lower – was ice grounded on the ridge, or was it still floating?
Jörundur – I think there was definitely ice pushing sediments on western continental slope of Iceland; little info about ridges in past; long way back, there might be a quite different situation on the ridge.
Tom Cronin – Farther north in Norway there are iceberg plow marks up to 700m depth; so probably grounded ice in a lot of areas.
Karl – Similar marks have been found on the Greenland-Iceland channel.
Karen Knudsen (from Denmark) – in the Scotland area they found grounded ice down to 700m depth …
Howie – Species reestablished themselves since the last Ice Age
Jörundur – If you go north of Iceland and look at diversity – number of species drawn on board - very few isopod species live in deeper parts of Nordic seas; different opinions of why low diversity in Nordic seas; are they the ones that have remained there during the ice ages, or that moved there since the ice ages? Interesting to see more molecular data on this.
Hal Borns - In the Norwegian coast, iceberg – 700m deep; sea level only 300m lower, so does that mean that the ridges have subsided tectonically since that time, and if that's the case, it was up higher back then, so whole different set of possibilities?
Tom Cronin – best studied area in the world, sills where deepw ater spilled over from deep water convection in the North Sea, so whole oceanography was different during last ice age; in terms of vertical limits I think you're right, Miocene, Pliocene, leading as opposed to forcing at isthmus of Panama.
____ - Where ice was grounded, unique in some way?
Tom Cronin- no, If sea levels 100 m lower, then grounded ice across the whole…
[missed this comment/question]
Tom Cronin – no, dynamics off Maine, Hal you've mapped that in detail, so probably known here…

Jon Eiriksson – modern interglacials….. I'm a geologist, not even a paleontologist, so I want to draw your attention to glacial conditions, glaciation history of Iceland, and secondly to the extent of glaciation during the last glacial maximum in Iceland. To study the glaciation record we need sediments – Iceland unlikely place for sediments because of conditions - sits on hot spot in mantel and there is in fact a plate margin where Europe and North American plates are spreading apart; Iceland is being rifted apart. Two consequences: subsidence is going on all the time; also sedimentation rates are high, partly because of volcanic activity and ice; geological history of Iceland goes only about 20 Ma back, so relatively young in North Atlantic area; rifting process has been going on all this time; fairly continuous record of volcanisms and sediments that are preserved in this system; an example of the kind of data we base or work on; Tjörnes – near top of sequence, dated sequence of sediments; correlation with paleomagnetic time scale, base is 1.7 Mya shows glaciation of the area at that time; accumulated in a near shore environment, slope to the subtidal marine deposition; quite a bit of fossil material in these sediments reflect arctic seawater being replaced as time goes on by more temperate, sub-arctic conditions – reflected by forams and other fauna; transition from glacial to interglacial. Top is about 100,000 years after bottom; Tjörnes sequence shows the number of times the Tjörnes Peninsula has been glaciated – 14 cycles within the last 2.6 or 7 Ma. It's a repetitive system of glacials and interglacials going back about 2.7 Ma before present. In Pliocene and Miocene there were local glaciers in Iceland; dating perhaps back 10 Ma. On my last overhead, turn to the last glacial maximum Tjörnes is a the northern edge of Iceland, so each of these glaciations was extending into the sea. Iceland is about 10% covered by glaciers today, so last time the island was covered by glaciers was 10 kya or more. The shelf is <400m water depth, most is less than 200m; during 18-20kya, when sea level was 150m lower than today, probably quite large areas of the shelf that were islands; the best dated extent of the glacial margins are in the northwest, and about 20km from the present coastline, shelf is >100km; about 60 km on a shelf that's about 100 km away in south; also series of islands even today. Compressed about 300m in the middle of Iceland, less so in outer areas; the refugia n on the outer shelf have been suggested by several others working with this; and certainly a possibility but we don't have the data, all the sediment cores are from the deep parts.

Karen Knudsen - East Icelandic Current branches from the East Greenland Current; get marine polar front crossing the Icelandic shelf; cores from this area reflect changes in the entire system, since it will reflect changes in the polar front, and reflect changes in entire North Atlantic oceanic system. Looked at cores in these regions, started with the foram faunal assemblages - isotopic composition of these, diatoms and dinoflagellates; established a modern data set from local area around Iceland; have data from west Iceland, east Greenland and north Iceland. With that we can reconstruct changes in the water masses through time on the North Atlantic shelf in both bottom and surface waters. Far beyond the last glacial maximum – 40 kya; concentrate on last 16 kya; one example - % distribution of benthic forams – some dominant in late glacial, and some taking over in post-glacial; same as shown from 1.7 Mya. In old succession, found species not found in Iceland today. In Europe we found the same kind of successions to one million years ago; same species migrating north and south; only know two from younger in Iceland; and they are almost similar. A bit warmer in last interglacial than it is today; where did these interglacial species go during the glacial times? No problem for planktonic forams. For

benthics, it's not a problem for North Atlantic shelf area, might have been in area all the time during glacial and late and post glacial; reconstruction - four degrees between last glacial max and today; tongue of warm water towards the west, the Irminger Current was there during the glacial maximum. Periodically; when North Atlantic current was blocked in the eastern Atlantic, there was strengthening of Irminger Current, lots of warm water pushed toward the north. In northern Iceland they were there the whole time; from southwestern Iceland, may have a problem, since we have species there that would not survive a glacial period – I think they immigrate every time we have a glacial/interglacial, presumably from Europe.

Jeanine – We talked about ice; we haven't talked about volcanoes – could there be local volcanic activity that would have opened up some warm water areas that would have opened up some habitat?
Jon Eiriksson – We have a record that goes through the glacials – we get bursts of water from beneath the glaciers, about 0 in temp; heat goes straight up and straight into atmosphere, thermal areas along ridges.
Karen Knudsen – May be important with water coming out on sea floor can see in carbon isotopes that there is an influence of thermal water coming up.
Eiriksson – There are thermal areas on the shelf
Daphne Fautin – Meltwater would be of lower salinity; so differences in water composition that would makes coastal water favorable or unfavorable.
Tom – Karen is that summer sea ice?
Karen – …
Louie Marincovich – I have a question for John Eiriksson, Iceland is about 20 My old, but people who study early tertiary migrations of vertebrates from 50 Mya, talk about proto-Iceland as being a feature.
Eiriksson – rifting took pace along ridge east of Iceland that is inactive today – that died out about 20 Mya; oldest rocks dated in Iceland to 16 Mya.
Marincovich – what is proto-Iceland?
Eiriksson – the Faroe Islands?
Karen –They are about 50 My old
Howie – Given everything we've talked about this morning and possibility that it might have been shallower , how shallow do they have to be for benthic organisms to move from Europe to Iceland along shallow ridge? Sea level and warming are not at the same time – so we have any feel for timing of these or anything else? Could organisms have made it across crawling?
Karen – I don't think they would be able at all to crawl that way?

Coffee Break

John Wares-how to interpret population genetic data and longterm residence
One of the big questions is endemism-in Iceland, N America etc. On what time scale are these species endemic? This comes into play when we use morphological data and genetic data. To what extent do genetic data match morphological data in Iceland?

Why are refugia important? They help us understand endemism and time scales.
There are a number of sources of unique genetic diversity-Candian maritimes, Southern population in Europe, possibly off coast of Iceland. Ordinarily you sequence a particular gene, mitochondrial DNA. We can collect a bunch of genetic data that may or may not be closely related. Ie amphi Atlantic haplotypes. Out of 700 base pairs, may have sequence that's common and a bunch of others that are only one base pair different. Defining haplotype-single base pair or other difference from other sequences collected. The length of the branches between haplotype hopefully represent temporal distinction between two groups. This is the inference we use to determine what areas may have had refugia for endemics to survive glacial periods. Example: Idotea baltica. There's essentially one group of closely related haplotypes (1 base pair) found in both Europe and North America. Off of this we have a branch with three substitutions leading to a clade that are entirely Icelandic. Paper published in JCB involved 6, now its up to 8 or 9 haplotypes in Iceland. There's an even more divergent clade in Canadian maritimes and another in Virginia (extent of sampling is just Virginia). If we believe that Iceland divergences are much older, want to see if they correlate with morphological divergence. If we have rate of mutations, can estimate divergence. On order of 100-200 kya. The same can be said for Canada and Virginia groups. We wanted to compare genetics and morphology of these groups. I was hoping to…Morphologically, Iceland group completely indistinguishable from Europe, and so is Virginia group. This is a question we need to focus on ecologically. If we have genetic but not morphologic, how are we going to find meaningful ecological differences.
Cliff: What was your range of sampling?
John: Geographic sampling is the biggest question. Only have I. Baltica from Iceland, …not from Northern Norway, Greenland, Faroes. North America-only have four regions.
: How many indiv
20, 40 –missed answer.
Chris: missed it.
John: breeding and behavioral studies upcoming on the VA, new England, and Norway populations.
Agnar: doesn't think it could have survived in Iceland refugia
John: Agrees it's hard to believe. Geothermal refugia? Somewhere there is a source for very unique diversity that so far has only be sampled in Iceland. Christy is going to Faeroes. If anybody has any samples, I'd be happy to take them.

Christy Henzler:

Pretty clear that we have an Iceland group that falls out on your haplotype network. So, Icelandic refugium. Holder et al paper on rock ptarmigan finds it as well. Preliminary data on amphipod, out on poster in hall. Have sampling from throughout eastern US and Canada, Norway, Ireland, France, Iceland. Not only a unique Icelandic clade, but a unique clade in France, one in Ireland, and a mess in North America. Beginning to see same pattern in Iceland as found for *I. baltica*. Molecular data indicate refugium in N Atlantic, not in Europe, not in N America. Sampling hasn't been adequate in Faeroes. I'll be going to Faeroes this week, talk to me if you want anything. Need sampling from

whole region. These are the clear examples, but I want to bring up a messier example, *Balanus balanoides*. We find shared haplotypes between Iceland and N America but not between either of these and Europe. Two big haplos from Iceland/N America and between those two we have a whole bunch of haplotypes from Europe, lots of separation among them. One shared (Iceland and N America) has unique N America haplotypes branching off and unique Iceland ones. The other has two haplotypes from N America branching off but none from Iceland. The first one mentioned, diversity in both areas, using mutation rates from Trans-arctic interchange, we get the Iceland branches being 60 kya +/- 17kya. Refers to itself???
: When are you dating the interchange?
Christy: 3.5 million y a.
: We have come up with same number using isthmus of panama, and these #s fall in with data from other invertebrates.
: Do you have data from Pacific?
: Yes, and branch is much longer.
Howie: What about ships from age of exploration?
John: They (*B. balanoides*) don't foul.
Steve: Yes they do.
Christy: But the unique diversity suggests not coming from fouling.
Maria (?): How do you deal with the problem of new introductions? France, lots of introductions-how do you deal with it?
Christy: our France haplotypes can't be traced to any other sources, they are on long branches, and we sampled pretty heavily. Christy pointed towards Iceland shared with N Amer, the one without Ice diversity, and said that it could be an intro because no diversity.
Cliff: More evidence for long term history because gotten more samples from someone else.
: Have you done any more sampling in belt seas? Does it occur there? Spain etc.
I think you've got some major holes in European sampling. Need to take deeper into North sea areas into account. In plants, we're finding very high diversity in the corner of the North Sea –Helgoland. Bet that some of Iceland haplotypes will go with Europe types, but haven't hit the right samples yet.
John and Christy: agree need more sampling.
Tom Cronin: Why refugia and not peripheral isolates or something else?
John: Its becoming a common catchall. Might not be right idea, especially given our sampling.
Tom: So its particularly because were in a glaciated area.
John: Can genetics uncover an unglaciated area if most expect it to be glaciated.
: What about source pops, and are these neutral mutations.
John: third position, typically assumed to be neutral. When we see large amounts of diversity, use it to estimate theta. Given mutation rate, you can make some rough estimates of the age of the haplotype in order to achieve that diversity. Its much more than would…
Geerat Vermeij: *B Balanoides*, is in the Arctic. Don't think you have to specify unglaciated for it to be a refuge.
Steve: mostly underwater most of the time (b balanoides)

: to gain that much diversity is difficult in such a short period of time. Need more sampling, but Christy's data is much more clear, because she has clades of organisms and those are more convincing.
Cliff: we see these places as distinct over and over again. I think they will hold up. We've found them distinct in lots of taxa. For any one species we'll never know the answer, so important to have lots of comparisons. My 10 dollar bet that it will hold is still out there.

Einar Árnason:

Population geneticist, interested in fitness variation. Possible to use phylogeography to make inferences about fitness. Studied mitochondrial 250 base pair. Tree based on 1300 individuals, 60 haplotypes approx. 4 high frequency haplotypes, A, E, D, G in order of decreasing frequency. Rare: C, 1 % Atlantic, 4% in Iceland. NI is another rare one. Lots of homoplasy in the tree-everywhere. We did a study, on poster outside, to resolve this geneaeology. Took larger fragment of chromosome, what happens to structure if add more sequence areas, longer sequence areas. What happens: structure remains, 4 high freq haplotypes. G increases in one, A-D goes from 2 to 4. A to E branch stays at 1 mutation. If you look at geographic dist of these haplotypes, there are clines. High frequency haplotypes have trans Atlantic clines. Intermediate pops are intermediate in frequency for all haplotypes. Can only be due to gene flow, the clines are regular. The haplotype most frequent in Baltic is haplotype that is closest to A. A is most frequent in Newfoundland. E is Baltic high frequency type, A is Newfound high frequency type. A is found everywhere in Atlantic. E frequent in Flemish cap. How to explain cline? Four possibilities. Maybe refugia, maybe drift and then restored gene flow. Maybe on mitochondrial chromo, other adapted types to Baltic and Newfoundland, the polymorphism is balanced by gene flow and local selection. He doesn't like the preceding explanations, because the tree is shallow. If really isolated or balanced polymorphism, then would see more divergent clades. The Baltic is most special location of these populations, and therefore selective effects should be greatest, and should be most divergent, but its actually closest to the Newfoundland. Selective sweeps??? Doesn't believe that either. His idea: George Williams Sweepstakes Evolution book. Cod characterized by sweepstakes reproduction. Mito types carried by females carried to high frequency very rapidly. Mitochondria don't have anything to due with rise of frequency. That's the idea I'm trying to promote as explanation for this tree. Phylo is fundamental to allowing me to interpret this data this way. Context of phylogeography can be useful for saying something about selection and fitness variation.

Andy Pershing: Are you going to get immigrants coming in from outside or not?
: Yes, he would expect immigrants. 1962 nature paper, cod tagged in North Sea and taken on Grand Banks 2 years later. He guesses that routes are via Iceland and then along American coast. On West coast of Greenland, finds cline in frequency of haplotypes. He thinks migration belt wraps around coast of Greenland. Cline in allozymes along west coast of Greenland also found by someone.
Geerat: Mytilus sor??? Sp in Greenland and N Pacific. Any evidence that your haplos are also in N Pacific?
: No. You think there's a refugium?

Geerat: multple invasions or a population once more widespread and now restricted to either Baltic or Newfoundland.
: not restricted to Baltic, found in all, just most frequent in Baltic. 4 types more frequent than 10%, found all over Atlantic. No endemisms.
Phil Williamson: evidence of parent fish returning to area where natal? Some cod return to area of seafloor where born, 2-5 years previous.
Einar: Disagrees. No evid in mito data for that. Poster outside, have Faeroes cod. Get a negative sign on FST. Consistently – wherever we look within a stock. ANOVA for whole Atlantic, 85 % OF VARIANCE explained. If I take away genetic data and use type simply as names, then 14% is explained. If discount genetic differences, get more variance explained. Tells me that cline is driving divergence. Why are high frequency haplotypes so frequent?
Cliff: one possibility-the A haplotype just happened to be one that colonized NW Atlantic after extirpation by glaciation. See a # of descendants, and that's why its so high frequency. Baltic-purely matter of chance.
See a small # of other haplotypes in N America due to gene flow. Amount of divergence is consistent with that idea.
Geerat: there was a point in N America where glaciers stopped, and cod could easily have gone south.
Cliff: until we start finding old haplos in that are, no genetic evidence of long term persistence on both coasts of atlantic. This broad sampling is more persuasive than the more limited data we have.
Dave Rand: anything about the sites that lets you address homoplasy?

COMPUTER SHUT DOWN. MATERIAL ADDED FROM HANDWRITTEN NOTES.

Handwritten notes:
John: This brings up the fact that there is still lots of phylogenetic uncertainty.
Einar: Possible that there are multiple E typos. Sequenced 300 individuals and it still holds up.

Snaebjörn Pálsson:

Polar cod:
-circumpolar distribution, very little differentiation
-closely related to Atlantic cod, but very different life history. 1% of fecundity of Atlantic cod.
-N. Iceland, N. Norway rare on tip of Greenland
-variation: location and time of spawning, some other morphological variation
-previously studied with allozymes and RAPD. Only 1.76% of variation was between populations.
-variation in Iceand is largest of the 3 regions sampled
-variation decreases as you move North. N is incorrect for combined cyto and space for Icealand???
-no geographical structure. FST=1.25, spacer 0.25

Jerry: How mobile are they?

: don't know. Often found close to icefront, socan track it.
Jerry: it's in Pacific as well? Don't know if cline is replicated in Pacific?
: No. getting samples though.
Chris: How big is the spacer?
: 75 bases.
Andy: any data on what cod were doing in the ice age?
: there are scales for Atlantic cod but he doubts it for Arctic…
Mary: if highly related, can you use polar cod sequence to see if A haplo for cod is most ancient?
: might be possible.
Geerat: Icelandic resembes old Norse more than modern Norse. Could there be a restriction of range of the haplotype? (ie the Icealndic)
Cliff: isn't the language thing about rates of evolution?
: resemblance to old Norse is overstated because Iceland deliberately purified the language.

Afternoon Sessions, 2:30, August 11, 2003

Jeanine Olsen-

1. Algal connection with Iceland-all from Europe
Fucus, *Zostera*, …*Ziponia* (?)

2. Is there a balance between richness of western and eastern sides? She thinks the richnesses are unequal. Lots of cryptic species. Algae have a lot of morphological stasis. Plus history of taxonomic splitters, most of whom live in Europe. We need to be careful about that with algae especially.

3. Dunton 1992 paper, arctic algae 2-10% of Pacific algae, whereas marine fauna was 30% Pacific origin. Someone has looked more recently and says 50-70% have a Pacific connection. We really need to look into Pacific effects on recolonization. To get at big phylogeographic questions we really need to incorporate that angle.

4. What we know about recolonization on European side: Populations of 1 species that are strictly limited to Euro side, there are N/S shifts corresponding to glacial periods. Refugia in the south of Europe. Populations of species on both sides of Atlantic, get a wedge effect, isotherms more spread apart on eastern side, and not much rocky shore on west side. Recolonization usually comes from East towards West. BUT *Zostera* has

North/South fluctuations like the solely European species, and it's a soft sediment species. Think that they are going to find link between Pacific and West Atlantic, in shallow time, for *Zostera*.

5. Every time we look at a new group we find evidence for introductions. Ex-Fucus serratus? In Canadian maritimes, known introduction, evidence of introductions in at least 4 or 5 of their studies.

6. What does it mean if we see zero sequence or haplotype divergence? Is it recent? Some bizarre demographic expansion? Ie the Cod example, demographic bottleneck. Widespread dispersal and admixtures?

Andy Pershing: Unequal richness, and if richness in east is false, then…?
Jeanine: For specific genera, more speciose on one or other coasts, but might be artifact
Chris: European coasts much richer in species
Jeanine: Need to be careful about the lists…
Geerat: You say its an artifact; people have looked at genetics. Crepidulid genus, find cryptic species in south part of western atlantic. I don't think its an artifact. Fewer species in most groups in northwestern atlantic.
Jeanine: Retracts her point, she thinks it is richer, but meant to urge caution.
David Rand: Are there good species found on both sides….?

Agnar Ingólfsson

Features of Icelandic biota
-European
-boreal, not Arctic ie list of 37 obligate intertidal in Iceland, 35 also occur in Britain. Not aware of any endemic arctic intertidal sp. Small subset of that of Britain, just as it is a large subset of those found in Norway.
Conspicuous missing species: they ought to occur here if you look at their distribution in Norway and Canada-*Littorina littorea* & *Patella* ???? Also no mosquitoes…☺
Littorina did make it to Iceland in an earlier interglacial. Don't know why its not here this time around. I have a distinct impression that algal biomass is greater in Iceland than Norway, but I don't have any evidence to support that.
-South coast sandy and not many macrofauna or much vegetation
-Sea temperature 11-12 C on south coast and decreases clockwise around island. This has a profound effect on the distribution of animals and plants. Many sp reach distributional limits. 37 obligate intertidal, 9 reach limits toward cooler limits, 0 reach limits toward warmer limits. 162 intertidal-subtidal species in Iceland. 20 reach limits towards cooler waters, 1 reaches limit in warmer waters. So-richness decreases around island in clockwise direction. Examples of what's missing on eastern coasts: green crab and *Nucella*. Mussel and barnacle biomass is considerably greater in east than in southwest.

Lan:what's the distribution of ice scour?

Agnar: Very limited to estuaries and closed bays. Very occasionally 1 in 12 years, it comes from the north.
David: hasn't it changed a lot in recent years.
-in 18th and 19th centuries, sea ice
1960s, got pack ice, but they don't usually get icebergs
Jon and ???-less vegetation where you don't have the predators? In eastern N America, mussels lower? (K missed it) In hierarchy than algae, you should have less vegetation without predators
: Ascophyllum diminishes as you go thru these communities as well.
Agnar: still very luxuriant on the east coast.

Howie Spero

Temporal perspectives of climate change, the Cliff Notes version
Oxygen isotope explanation: Paleooceanographers use stable isotopes to get at climate. All the O isotope variation is due to changes in amount of ice on the continents. DelO18 difference between your sample and a standard. Positive direction, more O18, negative direction, less O18. When evaporates, more O16 goes into clouds and falls on continents. More ice, more O16 pulled out, ocean more enriched in O18. When ice melts, O18 values decrease. The colder the temperature, the more negative the ice is and the more positive the ocean is.
Graph from Andre Droxel?? He's going to give Cliff a set of refs.
Oscillations in figure are heartbeat of climate, growth and melting. Down is melting, up is refreezing. Pliocene and Miocene, oscillations aren't very large. At 3.5 mya, transition to more positive? (K might have heard this wrong) values and larger amplitudes. Between 3.3 and 2.7 mya go from period of very little oscillations to bigger oscillations and more positive del values. Essentially, closure of Isthmus of Panama and shunting of warm water northward in Atlantic triggers this. Oscillations in ice volume changed from 41,000 year cyclicity to 100,000 years cyclicity (happened 700,000years ago) and along with this, go from small sea level change to 130 m sea level change during these oscillations. Now 8-10,000 years of cycle are interglacial, 90% of time we're in a period of glaciation.
0-90,000 years ago, climate over Greenland, warm is up, cold is down (cold more negative delO18). Take home message of ice sheet project: climate changes fast. Warms up very quickly (decades) and then takes a few thousand years to cool back down. Oceanic fronts move fast. Also, periods of time 30,000 years ago that were 50% of Holocene climate, periodic spikes.

: Shift from 40,000 to 100,000 cycles-why?
Howie: took awhile for northern hemisphere ice sheets to accumulate enough ice so that all ice didn't melt back. When cross threshold and some ice stays, then you get larger ice sheets and they last longer, collapses when it gets so thick its unstable.
Phil Williamson: This puts the refugia discussion into perspective. Ice is clearly not the exception, so maybe we should fix our phraseology. Species have been living under colder conditions most of the time. Psychologically we need to readjust our pictures. Also, there have been a whole succession of glaciations, species surviving might get hit in one and not in another.

Howie: It was considerably warmer 120,000 years ago than it is today. The most recent preceding interglacials were warmer. We haven't seen a world this cold since the Permian…
Cliff: draws more attention to taxa that were able to survive. Increases interest in what it takes to hang on through such long time periods.

Louie Marincovich

He's been working in Siberia and Arctic molluscan fauna.
Oldest rocks studied that relate to N Atlantic are 60mya, Arctic Ocean was isolated, only connected to Atlantic, which was much more narrow than it is today. 70 and 80 degrees n latitude are where his fossil beds are. (I think). Contain fauna that became extinct elsewhere, kept going another 5 million years. Thinks there might be taxa that arose in Arctic that got over to N Atlantic. He can make correlations between his sites and western Greenland. Arctic was a refuge in the Cretaceous. Might have spawned lineages that show up in N Atlantic. Unfortunately in Arctic, have gaps in record. Next time slice in Arctic is at 28 million. 1 fauna of that age, in N Alaska, late Oligocene. Found 1 fish in Gatidae. What's surprising is that it looks astonishingly modern. Trying to correlate it with Yorktown and Iceland, but got Strontium data that gave it the 28 date, couldn't believe it because the fauna look so young. Look like progenitors of ostracods in the arctic (modern). Just had an NSF proposal turned down to study that fauna. In 60 million year ocean, 10-15 C sea temp (not very cold).
No marine fossil deposits in Arctic until you get to Bering Strait-5.5 mya he thinks, based on appearance of ???Astarte in southern Alaska. The only Atlantic genus in the deposit.
Howie suggested maybe because so many rivers pouring into relatively isolated Arctic, the Arctic was really fresh, and only Astarte could survive. It lives in relatively low salinity water today. Main pt to be made about strait opening: water flow was southward when strait opened (climate modelers say so). Didn't reverse direction until Isthmus of Panama opened, which drove reorganization of ocean circulation.
3 pliocene transgressions in western Alaska, full of mollusks, 20 m thick, mostly Pacific taxa but some Atlantic, no Arctic endemics. One of those has been studied (2.5 mya), Arctic 6 degrees warmer than today, based on modern ranges of the species found in that deposit. Have 800 localities of Pleistocene for mollusks, but not well studied. In southern Alaska, 1000 m of Pleio and Pleistocene rocks to be studied. Limited study because helicopters are expensive ($600 an hour…)

Geerat: Significant and rich fauna known from Greenland. Nothing in common with the Alaska stuff. Much warmer fauna? Why?
Louie: an epistobranch, ???? (K missed it)
Well known Greenland faunas are subtropical. Arctic ocean low diversity-35 species of clams and snails. 150 species in Greenland, plus sharks, palm trees, corals.
Cannonball sea fauna.
Harold Borns: reasons to believe Bering Strait blocked by glacial ice one step back beyond the last glaciation to the penultimate glaciation. That would close off Bering Sea prior to 25,000 years ago. Also, ice formed on shelf across Siberia would have blocked rivers from getting into Arctic, preventing the fresh. Again, same glacial time period. The discussion has been violent. Pretty clear that those ice sheets did exist though.

Louie: Last glacial stage in Alaska, central Alaska wasn't glaciated. Mammals lived there easily. Don't know why it wasn't covered in ice, but well established that it wasn't.

Leifur Símonarson – Tjörnes molluscan fauna

Tjörnes is on the northern coast of Iceland, has some of the oldest beds in Iceland, rich in bivalves, mussels, forams, etc. [Showed graphic of stratigraphy of Tjörnes beds] 8.6 – 9.9 Mya; have series of marine sediments; probably deposited more or less continuously. Upper part of the section consists more or less of sandstones deposited in subittoral shallow water with littoral on top and bottom. The uppermost part is estuary, almost at the top is lignite(?) and here, at very top are littoral sediments again. The lower part of the section was deposited either below or just above sea level, then sublittoral shallow water then littoral sediments. We're trying to get an age on that - I can say that we have not succeeded at that. This is a pure lava, no reliable dating on that. Uppermost part dated to 2.5 Mya, and bottom – 2.8?? That's with Potassium-Argon dating, also tried to get correlation with paleomagnetic date, and alternatives for alignment with lava. About 3.6 My old, or something like that. Have about 110 spp. Of bivalves and gastropods, there are two prominent transitions: to sublittoral and back to littoral. There we have invasion of north Pacific into area, and at least 35 species we don't know from the Atlantic area but do know from the Pacific area, so they must have come from the Pacific. It should be pointed out that these sediments were divided by someone else in 1975. These [black bars] were older than invasion, so quite clear that the Bering Strait was open when the Tjörnes beds were deposited. We have temperature of Tjörnes beds – we used *A. islandica* with our data. We can't see any significant drop in temperature where Pacific organisms came into the area; warm loving species did not disappear, but kept on. The drop in temperature comes after the Pacific invasion. Sea temperatures of the Arctic were a few degrees colder, though the differences weren't as obvious as today, so the Arctic was probably a filter. The conditions farther north during the migration – the fauna is more Arctic than when migrating fauna came. We don't see any drop in species at change in temperature because species were able to handle it. At this time, about 50 species living in Iceland, I think that if we are going back in time that we have Pacific species here - at least 50 living around Iceland today.

Cliff – So we see a lot of Pacific things showing up at 3.6 Mya, but are there other times organisms pop up later?

Geerat – You do see some organisms show up later that weren't in the earlier beds – 2.2 or 2.4 Mya.

Louie Marincovich – The date of the intro of Pacific mollusks is 3.6 Mya. You noted that there were six or so beds[?] of Pacific shells – means migrations were more complex than we published.

Geerat – Which species appeared early?

Símonarson – [I missed these spp]

Cliff – And how early was that?

Símonarson – Maybe here [on diagram]

Jon Witman – Has anyone used the Tjörnes sequences to look at predator/prey stuff – looking at species interactions in the molluscan assemblage – Vermeij type stuff

Símonarson – It's not been done.

Geerat – It's barely been done for the North Sea basin, much less Iceland

Session IV

Tom Cronin:

I wrote some papers years ago on glacial/interglacial cycles and their impact on species that are pertinent to these discussions. Also, central American isthmus – I worked on early parts of Panamanian project – but refined date of closing of isthmus – 15-16 Mya, 7 Mya, 3 Mya - from deep barrier to shallow connection with a few little barriers. There's literature from Imperial formation in California. Probably most continuous section in North America well dated paleomagnetically.

The work on Tjörnes I did to understand Plio-Pleistocene climate change. These provinces hold well for ostracodes on eastern North America. I found 80 species of ostracodes in Tjörnes in total. Some are Atlantic, some Pacific. I've worked in Japan, we know these lineages well from Japan and Russia. We need to understand distributions in these provinces. Have data from a lot of stations. To better understand developed a large database in the Arctic. Some in deep and some in shallow water. We have similar databases for the Pacific I won't go into. We don't know a lot about the Arctic because deep sea drilling and ODP haven't gone there because of the ice. We have nothing from the deep Arctic or the ridges the way we do for the other deep ocean basins. We just don't know the Arctic except in pieces. We went and got material and visited in a bunch of places as many of these Pliocene stratigraphic units as we could to try to piece together the Arctic. As Dr. Símonarson said, it meant the Arctic was warmer than it is today. Stratigraphic correlation chart going from Barrin Island to Tjörnes, Russian sections, looking at marine Pliocene faunas in these regions. Tried to reconstruct the Arctic and reconstruct in my own group what others had already seen - the movement of my group. Tjörnes is great because of dating of volcanic beds, has glacial tills, fossils, early paleomagnetic data. These tills are old! All the ingredients to integrate the climate and the marine history of the region. Very extensive series of outcrops, fossils are quite impressive in some of these beds. If you get to take a plane up to Husavik, I recommend you go see it. Papers on these topics are out there – email me if you want to read them. The older beds may be older than this time scale shows –the really nice paper he[?] just published in Paleo Paleo Paleo. In general it shows fairly warm conditions in the early Pliocene, maybe late Miocene. When you get into Bredavik beds you start getting into the real glacials. In terms of the Atlantic and Pacific connections, it's not just a one time event. These tectonically driven events are complicated, closing off deep water maybe, closing off completely, reopening again. Ephemeral and intermittent until the final event happens, and yet the second filter is the Arctic Ocean itself and the environmental conditions up there. From 4 My up to present – the taxa that we really understood – the Pacific taxa and their migration into the Atlantic, and only one or two really did I find that went from Atlantic into the Pacific. The Japanese have worked extensively on Neogene faunas, and you don't see any Atlantic taxa appearing over there. Probably the

first ostracode described, *Cypria lutea*, is found in Japan. High diversification and only one or two representatives made it through into the Arctic. Not as harsh in terms of sea ice as it is today. Probably several degrees warmer at least at edges, probably for at least some of the time no winter sea ice. The water entering the Arctic from the Atlantic is >0 when it enters the Arctic, and is still greater than 0 when it gets to the North Pole, though not at the surface. Looking at the vertical structure of the Eurasian Basin, the temperature of that Arctic Ocean that we think is needed to explain these organisms migrating through the Arctic. It's pretty much a one way migration. Not an immediate or large migration, necessarily, once they got here, then subjected to north and south migrations, glaciations/interglacials.
Chris Maggs – What would it have been like for seaweed?
Tom – Rocky coasts that the seaweeds could attach to…. Louie?
Marincovich – Apparently there's plenty of rocky coasts in Canadian rocky islands.
Tom – Sea level would have been higher
Howie – Problem with going with algae is nutrients – no nutrients for algae to grow
Anthony – There is a substantial biomass of algae, not as high as temperate Atlantic, but about 30% of the standing biomass is quite high, though the production is low. All really well adapted to low nutrients.
Tom – I need to check on my ostracodes since they may live on algae and sea grasses – we use them as indicators.
Andy – If you're bringing in warm North Atlantic waters… has to be higher salinity and presumably higher nutrients – maybe the Arctic is much different now from how it was then.
Tom – I can't imagine it would be the same. The only core that goes back to the Pliocene is the Caesar core which Dave Scott worked on, if you believe their chronology. That's about it. The rest of the cores don't go back very far. Until they get the special mission-specific platform funded and organized…. The Artic is where I think they want to go. They took the ODP up, and got something….

Hal Borns – My own research deals with glacial history. I've been working in Ireland working with glaciers on the shelf, and nunataks in the Antarctic, and the northeast. I thought I'd contribute some ideas. I heard something on the radio the other day that seems to bear on migration. A container ship sank in the Pacific, and it had rubber duckies, and there was a herd of rubber duckies in the Pacific ocean. And they've now come up through the Bering Strait, northwest passage, and now there was a plea on the radio for people in Nova Scotia and Maine, etc. if they find them to call oceanographers so they can use this unorganized experiment.

Distribution of land ice, organisms and geology ??? If this is a help in organizing movement in and out of the North Atlantic, then this group could tap into this information and could constrain this information for you, and at the same time the biologists could constrain what geologists think – it's a two way street. Record of late-Pleistocene glaciation. Achieved maximum about 24 kya, covered all the maritimes – no land exposed anywhere. Starting at the last interglacial, coming up through 12 kya, you can

collect shells of various taxa and species, seaweed, seals, walruses, whales. About 50 different species of shells represented. Geologists have used this to get carbon dating of these guys. No one's looked where these critters came from. Archaeological record – where Indians were adapted to marine environment and built kitchen middens. These records are from the northeast, still some confusion with the dates. Let me show you where they exist. [Shows first overhead.] Ten years ago there was an argument over the extent of the glaciation. The ones on Long Island at Bridgehampton and Tobacco Lot Bay are really Sagamon in age – centered on 125 kya, ended about 90 kya. Moved in to glacial period of the Wisconsin. Water temps seem to be about 6 degrees C warmer. Tobacco Lot Bay is basically the same as Bridgehampton. It seems to be it's closer to the Sagamon border, more purely of Sagamonian age. Transition between Sagamon and Wisconsin – 90 kya or a little bit older for Bridgehampton. In Connecticut, there's a place - Saggety Head - dates back to the same age, temps are about same as today. Two units, a lower and an upper. The lower unit is Wisconsin/Sagamon, and the upper layer is Wisconsin, so colder. In Maine, northern Massachusetts, New Hampshire, those beds contain an Arctic fauna, and about 50 species represented, and have been well-studied. No one ever did anything with it from the point of view of the North Atlantic. Tom did some stuff with it. These are roughly between 12 and 15 kya, all represent colder environment. In Nova Scotia, a number of years ago the Canadians working in Nova Scotia came up with a series of ages, dated at mid 40 kya. Sort of equivalent in age with Tobacco Bay and Saggety Head beds. That bed has fossils in it that are a little bit colder than present, but not much. Have exposed beds that are 90-100 kya, to late post-glacial, 12-15 kya, but up in Cape Breton area have both younger and mid-Wisconsin (44 kya) aged beds. All of this can be looked at by this group to whatever this group wants to know in relation to the North Atlantic. Beds are there and well-exposed, all you have to do is do it. Howie talked about oxygen isotope business. The interpretation of O isotopes has been done through mathematical calculations. Little experimentation has been done, but we're trying to establish to a better measure, more precise, for *M. edulis*. Trying to get a better control on the southeast edge of the Laurentide ice sheet. Largest sheet of last glaciation except Antarctica. Poor understanding the chronology of this ice sheet. Poorest control on it in terms of environments and chronology. The group is trying to get the best picture of these ice sheets as closely to record derived from ice cores which is an annual record of events. Better chance of correlating ice sheets of world, correlating climates of the world. One way to do this is to better understand O isotope ratios, so there we are, just a lot of things going on.

Dave Rand – In these beds are there any specimens with adductor mussels - to get DNA – is any of the material preserved well enough to get tissue?
Hal – The stuff I've seen is pretty clean
Tom – I've seen some from muds with material on it
Steve Dudgeon – Would there be stuff in the bogs – like Caribou bog in Maine?
Hal – Yes, it's highly preserved
Daphne – I applaud you trying to get some more information on the oxygen isotope data, because it really depends on conditions
Hal – well, that's partly why we're doing this. If you try to date the earliest shells, produced just after larval stages, the ages aren't consistent, the ages are all over the place.

This progress has to go on, and if we're successful with this, we'll continue on with the mollusks that are right near the glacial margin – like *Portlandia*, *Hiatella arctica*.
Vermeij – a former graduate student ID'd this; with mussels – need to be careful how you deal with it, since they have high organic matter
Hal – I don't know; we haven't decided how we're dealing with *trossulus*.
We just haven't gotten to that point.
Cliff – I'm very gratified that the Nova Scotian dates seem to be at the height of the Wisconsin glaciation.
Geerat – that hasn't been independently verified. Might even be older.
Hal - yeah it might be older. By itself, it might not be looked at, but in the context of this group, it's more interesting.
With the exception of Gustafson working on Long Island most of its used for dating recessionary margins. Most isn't looking at the ecology.
There's real potential here for some really great stuff.

Gudmundur Helgason – BIOICE – Started in 1992, and its goal is to list all benthic invertebrates found on the Icelandic coast and within 200 miles from the shores, about 750 sq km. We don't have very much info about the area. Plus, since the Faroese could do it, we ought to do it also. We have been using their model, also, with some minor changes. These are the contributors, mostly in Iceland: Icelandic Ministry of the Environment, Fisheries Research Institute, University of Iceland, etc. In the beginning, we selected some 600 stations, now, 10 years later, we have sampled about 527 stations and 1290 samples. Seventeen expeditions and about 70 people have taken part. Sampling mostly by dredges, grabs and cores. Main problem with such intensive sampling is the sorting of the material. The specialists are looking at very small groups, have to have a sorting center – it's in town near to the airport, and now we have nine people [?] sorting specimens from these stations, they have finished sorting about 95% of these samples, about 4 million individuals. Only two expeditions left: in September, off the SW Icelandic coast, next year off the NE Icelandic coast. ID's are mostly by asking people to do it for us. Interesting barriers, so it's interesting to specialists. Have contacted about 100 specialists. There still are some groups left. All steps of this process are recorded in our database. We'll probably put it on the internet sometime for you to use. Here we have a small glimpse of the results. Some taxa that have been selected – number of species known before BIOICE, number found in BIOICE, and number of species new to the Icelandic fauna. Over 60 published papers using materials found in BIOICE.
Jeanine Olsen – How do you decide on a sampling station?
Gudmundur – Three ways. Chosen because of groundfish survey (150 stations), 450 were randomly selected using a random stratified model. Drew isotherms for 0.2 degrees, up to 5 degrees [???] used this info to select seventeen types of areas.
Cliff – Mostly deep, right?
Gudmundur – Between 20 and 1000 m
Jeanine – Do you see higher taxal diversity along these ridges we talked about?
Gudmundur – we see it there, especially the area west of Iceland
Phil Williamson – is there are lower size cutoff? In terms of groups there that aren't on your list? How do you deal with very small stuff, say <1mm?
Gudmundur – We sort everything > 0.5 mm.

Cliff – Can you use ethanol for last collections?
Gudmundur – We have some material in ethanol already
David Rand – can you give us a hint of what the sampling curve looks like? As you keep sampling?
Gudmundur – I don't have the data for that.
Svavarsson – Different sampling methods – we're not after a quantitative sampling, we're looking at distributions, a qualitative sampling. Our sampling will give us a very good idea of what organisms are in these areas
Ester Serrao – Are these Icelandic endemic marine species?
Gudmundur – Probably not – very deep.
Ladd – Could you use a subset of your data to look at effects of bottom fishing?
Gudmundur – We've been thinking about that. But we haven't done it yet.
Tom – Do you have any estimates of how many new species you've discovered by doing this?
Gudmundur – No, but so far around 2 %.

Cliff – I'm so inspired by this BIOICE project, because it would be so valuable to have this sort of distributional data for North America, if we hope to do the kind of work we're talking about here.

Tuesday, August 12th.

Cliff – opening remarks
Geerat Vermeij – As I listened to the meeting yesterday it became clear we need to clarify things. I want to talk about refuges, where they are, and different process, bottom up and top-down, and I want to say something about change, which is one of the themes of CORONA. A refuge to me is a region or sometimes an environment to which a taxon has been restricted. So at some previous time there was a larger distribution, and then the taxon was restricted. As you heard yesterday there are no endemics in Iceland, so from a species point of view, there are no refuges in Iceland. Finding a refuge implies that we know something about extinction. Let me summarize some things about the Atlantic. I want to distinguish between the east and west Atlantic, and I'm talking mostly about the areas north of Cape Cod in the west and north of the English Channel in the east. The fossil record indicates that extinction was extremely severe in the Atlantic, especially in the western Atlantic. In mollusks, 70% perhaps higher in barnacles went extinct in the western Atlantic starting in the mid-Pliocene. There is a wonderful fauna of some 400 sp in the Yorktown formation in Virginia that's 3.? My old and that is extinct. In both the Tjörnes section in Iceland and the North Sea basin, an accumulated loss of diversity of 50% occurred – so bad but less so. In Europe there is a significant refuge, where some of the survivors of the Pliocene refugium extended north again. Although extinction in the Pliocene was more severe in the western than the eastern Atlantic. However, the western Atlantic has become a refuge for the Pleistocene. Quite a few of the species from the trans-Arctic interchange were on both sides of the Atlantic. *Mya arenaria* is an example – it's on both sides and secondarily was introduced in the 16th century from the western Atlantic. [Another example I missed.] The genus *Cercaderia* is a long-standing Atlantic

group from the Paleocene, it became extinct in Europe at the end of the Pliocene and persists in the western Atlantic today. There is an example of *Tractodon*, a buccinid genus that is extinct today but survived longer in the western Atlantic than in the eastern Atlantic. I know of exactly two gastropods worldwide that became extinct in end of the Pleistocene. One is *Tractodon*……. In the western Atlantic and there was another in Morocco. So almost no species-level extinction in the late Pleistocene which is extremely counterintuitive. The extinctions are extremely poorly understood, probably several of them, eliminated Pacific migrants and Atlantic taxa alike. It seems to me that particularly in the late Pleistocene the invaders were particularly hard hit. Much of the fossil record in the world is concentrated in times of high sea level. Exceptions – glacial deposits, deep sea cores, etc. However, glacial deposits are very much less frequent than interglacial deposits. As Howie Spero pointed out yesterday the interglacials are very fleeting. Therefore we don't really know when things went extinct. With the exception of other microplankton we don't know the precise circumstances of extinction or speciation because there is so much missing from the fossil record. Let me now turn to climate change, since this is one of the concerns of CORONA as well as politicians. I have thought for a very long time about human caused extinctions, and about the extinctions that humans seem to have caused in the fossil record. What I'm about to say is fraught with controversy. The major and minor extinction events that we chronicle through the history of life are largely caused by a bottom-up collapse. General, not local. Most of the extinction events with which geologists are for the most part concerned involved the extinction of planktonic organisms including phytoplankton or those that act like phytoplankton (eg. Forams) as well as [? Missed this]…. Think how difficult it would be to get rid of a planktonic organisms completely. We're talking about trillions of cells distributed over vast areas. It's probably not too hard to kill off mammals, etc. yet plankton have been killed off extremely frequently. Triggering event – pulling rug out from under ecosystem, a productivity collapse, then many things that depend on primary producers will feel effects immediately and then it will collapse unless they have another means of metabolism – eg. those that depend on endosymbiotic bacteria. Despite the great climatic fluctuations of the Pleistocene, there are few if any extinctions except human-caused ones on land toward the end of the Pleistocene. Marine extinctions are conspicuously rare after the Pleistocene throughout the world. Let's compare with the mechanism humans are foisting upon the world. We're fragmenting formerly continuous environments, we're reducing area, mostly we're getting rid a of lot of high energy species that demand high areas, a lot of food supply. Additionally we're exploiting top predators, major competitors - we're removing the top. Boris Wurm and Jeremy Jackson and both their colleagues have repeatedly pointed out that we're eating down the food chain starting at the top. Though we've seen relatively little extinction in the ocean so far, we are taking it down from the top. Not only are these different in cause, but different in effect – I would guess the bottom up extinctions that were talking on the scale of El Niños – within 8 months you have die offs of seabirds, seals, etc. Moreover, because so many organisms depend on the primary producer, if you get rid of them you create a calamity. When you removed top predators and herbivores, you create a reduction in demand, which is bad, but the production system remains intact. Many kinds of organisms that would typically die in major extinction will persist in even what we are causing. Though we are clearly changing a lot of relationships a very fundamentally

different kind of mayhem than geologists have seen in the past. Why relate to CORONA? We should worry more about weather than climate – weather is on the scale of a single organism's life, while climate is over long term. I don't know about speciation, but I think that we need to think seriously about threshold effects rather than ___ effects when we talk about extinctions of organisms. Top down should be more gradual, Both kinds of extinction have important consequences – when species go extinct we are creating opportunities for expansion of other species to fill the gap. When you remove or severely deplete the incumbents, the distribution can become very different. All of these phenomena are traceable in the fossil record. Which gives us info on past distribution which nothing else can. And yet, good and intriguing as the fossil record is, it is an error to analogize current extinctions with extinctions of the past. We have to be exceedingly careful with comparing these kinds of extinctions.

Howie Spero – Given the fundamental extinctions that went on about 3.6 Mya, and the fact that there really is no evidence for impact that would have a system level effect…
Geerat – I'm not convinced that's true. One is about 3.3 and the other is a little younger, I think. (Southern Ocean and Argentina). By Permian standards, these are pretty minor. I don't think people have looked seriously enough, dating is always an issue, I realize I'm fighting a major uphill battle here. When most geologists look at this, they see oceanographic work and say it's ocean changes. I think that's too facile. I think the ocean can change in response to events that we have only the haziest notion of. I think we've been too quick to say that the reason must be in the ocean and atmosphere. How do you get rid of all those planktonic organisms? They should move with changing currents Andy – you mentioned alternate feeding methods, resting stage… do you see these survive?
Geerat – KT – diatoms and dinoflagellates with resting stages did better than those with none. There are times when those capable of shutting down do substantially better than those that can't. The problem – people are very happy making lists of those that survive and those that don't survive – if you were doing human history, you might want to start with the kings of England, but you don't want to stop there because all you have are names and you have no idea how they all got there. What does it tell you? Nothing. You need to know natural history. Even for the Pliocene where you'd think we'd know, we have only the barest idea. We have more than just names – need to look at ecological, evolutionary context of invasion, speciation and extinction.
Cliff – You've argued you can look at restrictions as a guide to extinction – not mass extinction. Are those bottom up?
Geerat – Yes they are – there is idea that there is a difference between local and mass extinction – I think this is not true – only difference is magnitude. But yes I think that if you are going to look at extinction identifying refuges is a major part of that – ecological refuge as well….
Tom Cronin– Just a clarification – you mentioned the incompleteness of the shallow-water record in a lot of the classic areas especially along passive margins, but in some areas, most notable is Japan there has been resolution of faunas through 10-12 cycles. I just want the biologists to know that it's not just the deep sea where you can see molluscan assemblages changing within a cycle, not just between cycles. It's very nice work …

Geerat – Unfortunately doesn't exist in Atlantic.
Jon Witman– You talked about the geographic extent of the refuges – what about depth as a refuge? Any differential pattern?
Geerat – Very difficult, can do it the way Tom Cronin does – if you know the requirements of the species; there are so many differences in depth distributions…

Steve Hawkins – from ecological viewpoint it's not extinctions of a whole taxa that matter, it's extinction of populations. Though we might not lose taxa completely, we are losing taxa from whole chunks of coastlines –
Geerat – that's why I said we're insularizing the world
Geerat – I think it's very, very hard to identify source and sink populations today. One of the most important tasks for population biologists is to determine where the source and sink populations are.

Howie Spero –we see major extinctions about 3.5, 3.6 Mya in the Pacific. Tom talked about the closure of the isthmus of Panama yesterday. We're at the point now in paleoceanography where we can see the changes in and get the mechanisms for extinction (possibly). Yesterday I talked about the oxygen isotope story. The same thing works for salinity. When delta ^{18}O is positive, then you've removed more O_2 from the ocean, and salinity is higher, low values are lower salinity. True all over the planet – the only difference is how much freshwater input.
Today there are only two places where water sinks to abyssal depths – North Sea and the Weddell Sea. Wally Broker [???] gave very stylized version of what happens in oceans – conveyor belt. Deep waters flow into Indian and north Pacific Oceans. Waters off the coast of California are about 2000 years old – so about 2000 years for the whole trek. Across entire Pacific there's a large upwelling zone. Trade winds transport water back across – the Atlantic – cross-equatorial flow of water from south to north Atlantic. That's today's conveyor belt – why does it flow the way it does? One reason – the Atlantic is saltier than the Pacific. The gyres in Atlantic are 36-37 ppt, in Pacific they're 34-35 ppt. The isthmus of Panama came up – trade winds takes Atlantic water up in mountains in Panama, rain comes down and drains into the Pacific. Cyclicity in climate plot – abrupt transition that occurs from 4-4.5 Mya… I always have a difficult time imagining how the isthmus of Panama popped up. In the Miocene – constricted flow of water as islands pop up. If equatorial flow exists, then won't have difference in salinity between the Atlantic and Pacific. Researcher in Germany – had some Nature geology papers – what we know the world did right after the isthmus of Panama – ocean drilling program (ODP) – two cores – one in Caribbean, and another in eastern equatorial Pacific. Looked at geochemistry of forams living in surface waters. If salinity is the same, forams should be similar (composition). If you go out to about 5 Mya, both cores give exactly same; at about 4.6 – 4.7 Mya start to see establishment of salinity difference at about 4.2 Mya. What this means is that flow had decreased so loss of water by rain couldn't be made up by current flow through isthmus. Can see the evolution of these salinity differences between the Atlantic and Pacific at about 4.2 Mya. Examination of what happened in the Pacific – went to north Pacific – and looked at the opal content of cores in the north Pacific, south of Aleutian system. The amount of biogenic opal accumulating in

sediments – shows an abrupt transition at about 2.8 Mya. Biogenic opal is basically diatom accumulation in marine sediments. Greater accumulation means increasing productivity, with crash at 2.8. Nitrogen isotopes are good tool for looking at how nitrates cycle through. Goes from values that tend to be low (+3) to +5, +6. as opal is crashing, see diatoms struggling to utilize the nitrate. They proposed that we're seeing development of north Pacific halocline – Aleutian low develops, closes off upwelling system, can't upwell through halocline, lose productivity system in vast parts of the Pacific. Potential effects on foodchain. Cliff will have the references to these. What happened at 2.8 in the north Atlantic? When exactly and why did the north Atlantic glaciate? With the closure of the isthmus of Panama – intensify cross equatorial flow in north Atlantic, brought water vapor into north Atlantic (it's a warm water current). This becomes the freshwater source that's now transported via the westerlies. In the Atlantic – cores – the key record is what's happening the percent of sand that's being transported into marine sediments. We see an abrupt increase in what's going into the system, related to drainage. With all the freshwater coming into the Atlantic, huge amount of river discharge into the Arctic, so surface waters can then freeze more readily - feedback system – freeze the Arctic – makes a whole part of northern hemisphere white, albedo increases, feedback increases – with Atlantic water flowing up through Nordic seas – still having open leads between continents and sea ice. We're really beginning to tease apart the ocean circulation system, from a nutrient productivity point of view, etc. I do agree with Geerat that the changes we see are due to outside changes – but can't forget that productivity changes are going to cause changes higher up the food chain. Becomes oligotrophic - influences downstream (ref to earlier Pacific stuff). The north Atlantic deep water was not functioning during the glaciation. The thermocline waters – much lower productivity coming up through the thermocline.

Geoff – what was the Amazon doing before the isthmus of Panama, and how does it fit into the overall? – important source of freshwater to Atlantic.

Howie – Working on last glacial cycle in Caribbean. With sea level lower, freshwater from Amazon does not seem to get into the Caribbean. Much more arid during glacial times – lower runoff.

Geerat – you could actually write a whole book on the Amazon, if you wanted to. There's a lot of debate on where the Amazon went before the Miocene – may have gone through west basin. Gigantic inland sea mostly freshwater, though some brackish waters as well.

Cliff – you're not persuaded that closure of isthmus led to collapse of productivity?

Geerat – no doubt that in the Caribbean the water became oligotrophic

Mark Costello – haven't mentioned – they're all in the Mediterranean as a refuge?

Howie – keep in mind today the Mediterranean is one of the saltiest bodies of water connected to the ocean

Geerat – misspoke when said Mediterranean

Tom- Mediterranean had deepwater inflow in the Miocene(?) but there's an excellent fossil record of cold water organisms – defines Plio-Pleistocene boundary. Didn't have any impact on species with bigger ranges

Mark Costello – For a place that's a mess it has a whole lot more species

Tom – It's a relict of global ocean – the Tethys – it has a tremendous stock of lineages, also margins of Mediterranean during Neogene (para-Tethys) lots of ways for things to isolated along margin – radiations we don't see other places.
Howie - Distinct species of forams in Mediterranean relative to Atlantic – symbiotic forams – upper 50-100 m of water – surface water flows into the Med, not out.
Louie – In recent years the Arctic ice cap has thinned by 40% - any changes in Gulf Stream?
Howie – We've seen more freshwater flow out of Arctic – could slow flow of North Atlantic deep water. Freshwater coming down east coast of Greenland
Steve – A lot of the species endemic in Mediterranean have sister species in Atlantic – vicariance event; limpets – [gave example] Some barnacles - at a subspecific level there's a Mediterranean genetic signature. A lot of the endemism has been created from the Atlantic as well as Tethyan relics
Tom – look at Red Sea, conspecifics?
Steve – has been looked at, but not closely related
Geoff – One of the things we've been interested in is the freshwater flow to the north, etc. how does increased aerosol delivery effect Atlantic.
Howie –Still arguing about how much iron could have affected during glacials; in regions with upwelling you don't have to worry about this, it's the low nutrient regions - no evidence of elevated productivity in these regions. For the North Atlantic the debate's still open.
Geerat – in North Pacific – showing iron limitation kicked in at same time halocline started.
Howie– The answer is the jury's still out.
Geerat - Have to iron it out

Andy Pershing:

This is a unique kind of science that I usually don't have an opportunity to do. Really a neat opportunity that I've found to be fun.
My job-try to bring a modern oceanographic perspective to some of the CORONA objectives. So here's a story about Cliff. Last year at Shoals, after the lobster feast, Cliff says "Andy, we really need to have some theory to bring it all together, and I challenge you to work on it, you need to read Hubbell's book." Then two weeks later he sent me the book.
The Idea: Trying to draw equivalences between different areas, like using isotherms. I don't think that those areas are equivalent, and I think those differences are going to be interesting, like daylight difference. Broad east west difference, variability about that mean temperature. I'm using temp as a proxy for lots of physical conditions. Wave stress, winds, etc. In the west, because you have highly variable air masses off of continents, you have a much higher amplitude seasonal cycle. In east, same mean temperature, lower variability throughout an annual cycle. I'm interested in looking at how physical processes impact biology – like interannual variability in the north Atlantic oscillation. The effect of the NAO is a shift in westerlies and the weather that goes along with them. Get higher amplitude of shift in the east! Amplitude of that signal is higher in east and lower in the west. If combine these signals (temp and NAO) (could multiply too, but I added), you get very different variability in east than in the west.

My hypothesis: This could have an impact on species distributions and diversity patterns in east and west. If have huge annual range of temperature, may need to be a generalist, whereas in east, you could specialize in your narrow temperature band, and sometimes you get clobbered and replaced. So, use Hubbell's book to test effects of variability on diversity patterns.
Hubbell's book: Says get rid of everything interesting, treat every individual equally-everyone has an equal chance of surviving. I'm going to randomly create species, each of which has a probability of not dying over a range of temperatures. i.e. varying temperature niche breadth. Neutrality condition – integral of these temp functions is equal. [See handout.] Force communities with different temperature time series with different temporal variability (long and short time scales). Hopefully this will provide some kind of idea of diversity patterns to test. I also have to characterize the physical environment. Someone must have done it, but I haven't seen the maps the way I'd like to see them.
Now for my fish story – it's very brief. We've heard a lot of talks – Agnar presented the idea that you can get transport of algae from Europe to Iceland. Maybe that goes against mean flow. But it doesn't have to be mean flow – you need for it to happen once to get a founder population. These random or episodic events are coming up a lot. Cod are a good example. They sit on their patch of ground and spew out lots of eggs. Gary Sharp-"The average fish is dead." If you are thinking about average conditions, you're not thinking about the conditions that are important for the species that actually exist.

Geerat: There are evolutionary questions about why so few tropical species become temperate, and vice versa. How is the Hubbell approach going to deal with this?
Andy: It's not. There should be a way to incorporate these different scales and processes, but for right now I am going to keep it as simple as possible.
David: Brian Helmuth and I are trying to link limits of species to models of fluctuations of physical variables to match distribution of species.
Cliff: Do a presentation later today.
Steven: We have a lot of that kind of data for the English Channel. Planktonic assemblage dominated by open water species, 1903-1987 with some gaps, we restarted last year. Point sampling, but trying to give it a broader perspective. Those kind of sea temp records don't look dissimilar from your cartoon for the east. You could go to Woods Hole for squid catch records. (?) We looked at our squid catches and got nice relationship with NAO.
Andy: We've been doing that with copepods. Good idea.
Tom: The most important point for geneticists-multidecadal oscillation because of impacts on both sides of Atlantic and time scales that are important. Meeting in Galecia, Spain – your colleagues were there, yes? The periodicity of this cycle, people thought was 8-10 years, its still uncertain whether it is a cycle, but possibly 60-80 year cycle to it. Good evidence that its out of whack with what it was doing over last millennia.
John: Rick Grosberg's lab shows population sampling important for genetic stuff…
Steve: prediction of NAO positive weather in a warming world. Warmer and wetter. *Balanus balanoides* depend on phytoplankton blooms, if those get messy things will get interesting.

Mark Costello

I don't know another initiative in marine biology that brings together people across the Atlantic for several years! Three items – coordination, communication (email list), and workshops – meetings are the only deadline, we're network of scientists, which is already fostering additional funding and proposals. Additional things we'll do this winter – set up a network of marine laboratories. There are already networks in both North America and Europe, but they don't cover everything. And we'll set up a network for getting specimens for scientists.
Secondly, there's a lot of people out there collecting things anyway – for example contractors – big collections museums don't want them – they're duplicates of what they have – if stored in ethanol could be very useful to the CORONA project. Consulting projects are quite keen to get something out of it by collaborating with scientific projects. Surveys of opportunity. Might need to ask them to use ethanol not formalin. It may not be the full picture of sampling, but may be another sources of free material.
Put together a North Atlantic register of marine species – European list of almost 30,000 species, most of which are in Mediterranean – but Atlantic species have been derived from, or vice versa. Not database downloadable. Bay of Fundy list by next Spring. Also have Cobsequid database in Maine. Limited in quality to expertise we have available. Have taxonomists take a look – interesting debates about taxonomy – that's how you improve the list. BIOICE will probably be available in the next few years, etc., then start classifying species by characteristics so can get information from it. OBIS. Could start looking at patterns. Hopefully provide ideas for additional proposals.

Tom – Are these databases you're accumulating on what's actually living there today, or on past surveys back through the 20th century, because they're not the same?
Mark – everything from the last century – is included in ERMS, because it's hard to tell if they're really extinct.

Louie Marincovich – What was OBIS database you referred to for ocean temperature data?
Daphne – Accumulated from various of the oceanographic sources, all brought into a standard - .5 degree coverages of about 200 parameters, can go to hexacoral site and all the meta-data are associated with them.

Chris Maggs

First inspiration was CORONA – and the first meeting. Framework six was second inspiration – prepared to dish out money for research networks. Quite a lot of money. I don't remember the details but when we put this together with 11 partners, it was 7 million Euro – quite a lot of money you can spend on different things. Leaders of these 11 partners, quite a lot are women. Next, finding a title, etc. – Acronym is DISPERSE – the RS stands for Rising Storminess – intergovernmental panel – predicting more severe storms in future. But we're also observing right now much stormier weather, we can see

changes happening now. Then work done by Ester Serrao and Susan Brawley – observations on gamete release in *Fucus*. *Fucus* will only release its gametes under calm conditions. They already know that in some months there are just a very few of those days that are calm enough to get gametes released. – So what effect would this have ?? Quite small changes could have very major impacts. IBM – individual based modeling – look at effects on particles – propagules moving through water. High resolution molecular markers – what this can enable us to do for both animals and algae – predict where things are going to go. Hope to get a response in the next few weeks.
Problem – no eastern European partner (they don't have tides, and we were interested in tides). IF we don't get backed we'll resubmit.
Cliff – This can fund actual research?
Chris – They fund salaries.
Cliff – Trans-Atlantic?
Chris – Susan Brawley is on the grant.

Tuesday afternoon

Anthony Chapman:

Nobody knew much about distributions of assemblages on rocky shores throughout the North Atlantic. This is different from other parts of the world, i.e. Mediterranean. If you asked, they would provide you with a list of biosynopses? A community type classification. Brits have a biotope classification system, not widely known even among British ecologists. There are key species that help identify the biotopes, and its somewhat quantitative.
But among those assembled, have genotypes and mechanisms creating patterns, but don't have a biotope or other type of community type map or knowledge.
I think it would be a good idea to have a sampling program. Rather than using a classification scheme to analyze assemblages, use some kind of gradient scaling to see how communities laid out over geographic gradients.
Not many realize that the fucoid assemblage in Europe and West Atlantic only covers 10 degrees of latitude in the western Atlantic. Reasons: north, ice scour, south, too hot. That shows you what kind of a hole there is in knowledge. Should be analyzed quantitatively.

Cliff-what do you have in mind? Count all species, or ID 20 or so and survey.
: on rocky shores, enough expertise to do quadrat sampling and estimate cover.
Steve Dudgeon: you clearly find big differences among sites if use species names, but would you if you use functional groups or some other thing in the analysis (obviously want species data)?
: I think species are ecological units, they aren't functionally similar.
Steve Dudgeon: you're going to get sites that differ in an ordination if you use sp names, but you might not be able to determine similar enough sites for sampling.
: I'm actually not proposing a program or anything
Steve: planned comparisons. If you stratify quite a bit you can get rid of noise. If you choose a couple of shore levels and do things in a simple way, use obvious large species,

photographic sampling, it would be simple to do, and everyone could spend a few days getting it.
: I agree. Then the question is what can you do? You want to find explanations. Ordinarily we look at depth distributions, but there are small- and large-scale geographic differences in North Atlantic. I.e. Gulf of St Lawrence, 1/2 size of North Sea, doesn't have kelp beds. Has kelp, but not beds. Why? Another ex: Most of coast of Newfoundland doesn't have kelp, it has sea urchin barrens south coast of Nova Scotia, no sea urchins in the kelp beds. Unheard of elsewhere. Most of lobsters caught in that 100 km of coastline. What's more interesting to this group: as you move north on both sides, you move from animal dominated to plant dominated communities, that's a geographic trend. Occurs in different places on the different sides and with different animals. On exposed coasts. There might be different mechanisms, but these are geographic trends that you can see. But we don't have the assemblage data, particularly in the north, to be able to formulate worthwhile hypotheses that could be tested.
Tom Cronin: For decades, this is the std approach for anyone working with meiofauana, planktonic forams, etc ("this method" is the method that ??? is proposing I think).
: through the trophic web is what I'm talking about.

Emmett Duffy:

What I'd like to talk about, why does diversity matter? Much of our discussion is patterns of diversity and what are the mechanisms maintaining them to what might those patterns mean to functions of ecosystems etc. People have already raised these things, I just want to pick up on them. Two big questions to answer in CORONA framework, stemming from general pattern of lower diversity on west than east side of Atlantic. One is at community level, other is at population/evolution level.

1. community/ecosystem level

The first issue is the one that has gotten a lot of press in ecological literature-potential influence of biodiversity on ecosystem function. There are different aspects of this: how does species richness and composition influence functional properties like trophic transfer and productivity. There are a # of ways of looking at this. After a year or so, I think my colleagues in hard substrate systems who know something about this system, it might be more profitable to focus on dominant species instead.

2. What are the population level consequences of having lower diversity in a community. Ie if you consider one of the grazers that occurs with one species/genus in west and several species/genus in east, ie Idotea, we can ask several questions about how lack of congeners or other competitors might influence niche breadth. Geerat brought up idea of ecological release earlier today, and how that influenced distribution of species. Hypothesis-fewer competitors might lead to change in ecological amplitude or niche breadth and we could also look at how the phenotype of the animal changes. Let me give you a couple of examples from Geerat. Limpet intertidal in west, but not in east, no other limpets in west. Nor do they come into the intertidal in Iceland-Agnar. Someone said they do come up in Britain. Also-*Littorina littorea* get bigger in west than in east, has morphology changed in response to lack of competitors? I'm hoping more than understanding that there may be taxa on both sides that lends themselves to asking these questions.

In addressing the issue of ecol release, empirically not that difficult to get at, breadth of habitat distribution, breadth of diet with and without competitors, whether those differences are genetically determined or phenotypically plastic. For short-lived invertebrates, could do in the labs. I.e. can raise crustaceans and gastropods.
That's it.

John: one of Emmett's techs is sending a collection of *I baltica* to Hans Deter ??? in Helgoland to see if its genetically distinct. They can live for 3 days in Styrofoam.
Anthony C: there have been two disasters (accidental introductions) at Helgoland,
Cliff: can't you do this with your amphipods?
Emmett: maybe, I don't know enough about the distributions…problem: might not have enough species that occur together to have a richness gradient for local ecosystem function.

Brian Helmuth:

Andy gave me a great lead in.
We want to understand current day distribution patterns to understand past distributions. Problem with rocky intertidal is that it's terrestrial as much as it is aquatic. Points about how we measure temperature for intertidal organisms.

1. recent studies, what drives physiological performance is not just mean temperature, but body temperature when water goes out not just water temperature. we really don't understand what these temperatures are, and patterns are much more complex than we usually think. Based on lots of terrestrial work, temperature of ectotherms is driven by multiple variables when exposed to air.
2. temperatures of organisms at low tide not equivalent to air temp, and two organisms exposed to same climate can have different temperatures due to infrared radiation to sky, radiation between organisms, and more. Multiple things drive body temperature, and amount of heat they take up is dependent on organism itself. Neighbor could be 15 degrees warmer than you. To account for the effects of aerial exposure, we need to incorporate all of these variables. We take climate models and predict temperatures of these animals, and then link that to physiological performance measures.
3. patterns in body temperature over latitudinal gradient, largely due to effects of tidal height. That determines when they are terrestrial and when they are aquatic. Often see very regular patterns. From day to day, change time and amplitude. Some parts of world, no midday exposure, or very little.

ex: North to south sites along west coast. Puget Sound sites, huge amts of midday exposure. California, no exposure whatsoever.
So, we've measured temperature in intertidal with robo-mussels, recording temperature specific to that "animal", matched to specs for real animals. All at one mid-tidal height, 13 sites plus 2 in Puget Sound, patterns are complex. Using broad metrics of temperature-chronic exposure and acute temperature (sort of). Found that there really is no pattern. In central Oregon, seen high temps, seen mortality events in Puget Sound and Monterey, which are some of the hottest sites.

If we want to look at effects of climate change, we don't have a simple North/South gradient. Challenges idea that we should be looking at southern ends of ranges to figure out what's going to happen. We may start to see disjunct populations if holes of unsuitable habitat are big enough.
We think same thing going on west coast of Atlantic. Ortnan in 1928 suggested it for the UK.
What Dave Wethey and I have been doing is taking climate data, plugging into models of tide height, see where low tide corresponds to high insolation periods. Do species distribution patterns relate, or is it just dispersal patterns?
Take home: Patterns are complex and often counterintuitive. Also, two organisms exposed to the same conditions may have different temperatures , i.e. linked to rock temp vs. solar irradiation. These quantitative methods give us a null hypothesis we can go out and test.
Cliff: depends on how much of population is intertidal. Lots of Atlantic species have huge subtidal populations as well.
Andrew Pershing: expect no comparable effect on subtidal community, so if they aren't decoupled, its not important, but if it is, it might be.
Brian: Subtidals show no difference in growth rates, intertidal populations do. The population genetics will determine a lot of this (intertidal vs subtidal).
Andrew Chapman: Density of individuals is important for staying cool. The higher on shore, the better the survival.
Brian: it's in the models.
Tom Cronin: you're working in area on west coast that has widely spaced isotherms, with little variation in water temp. should go to a place where have steep thermal gradients. In other words, when you showed plot with no change, is that surprising, given that there isn't much of a water temp gradient?

David Wethey:

At the last meeting I talked about the northern geographic limit of *Chthamalus*, which on the American coast of the Atlantic is at Cape Cod. In the UK the northern limit of *Chthamalus* is somewhere up in Scotland. Cape Cod is an oceanographic boundary – Gulf Stream goes off shore, and there can be a 10 degree C change on each side of Cape Cod – warm water south, cool north of Cape Cod. Tens of thousands of individuals on southern bridge of Cape Cod Canal, seven individuals on northern bridge of Cape Cod Canal. Air temperature and convection – those sorts of phenomena at low tide, and if you also account for the thermal conductivity of the rock and conductivity of water and rock at high tide – balance of what's happening in rock (warmer or cooler than air depending on time of day/geography) in northern bridge they're bathed in cool water, while in southern bridge they're hotter when the tide recedes (because water is hotter). A competitor of *Chthamalus* dies in the intertidal south of Cape Cod. Translates to differences in condition at low tide, end up with very sharp gradients. Need to be careful when we look at biogeography – need to look at both water and air temperature, otherwise we're missing part of the story. In this case, biotic conditions are mediating biogeography, taking into account both aquatic and air conditions. I've been doing some of the same kind of analysis at the Cape Hatteras boundary. The southern limit of

Semibalanus is near Cape Hatteras – is it too hot in the south, or something else? In Europe *S. balanoides'* southern limit is near the corner of Portugal/Spain. *Semibalanus* is found in the shade in the lower intertidal north of Cape Hatteras, you don't find it south of Cape Hatteras – you can either measure it or model it – you can show that the conditions are in excess of the thermal limits of these species south of Cape Hatteras. I've done the same thing in Spain where the published southern limit is – if you look at the conditions at ??? – modeling says it should be fine. But Lisbon should be fine too.
Steve Hawkins – There's a hell of a lot of sand between ??? and Lisbon.
David Rand– In the Vancouver, Puget Sound area *S. balanoides* is found by Vancouver Island – it's the farthest southern population – southern end of the strait of Georgia (disjunct, other populations in Alaska). There's a biogeographic boundary here, but it's not what you'd expect – it's restricted to the warmest part of the bay – at the upper end of its limit, and it's absent from the place it would do better physiologically. We need to be very careful when we look at biogeography – often interactions between species may be more important than or mediated by these conditions. Impact of those conditions on communities rather than those species may determine those boundaries.
Cliff – comparative ecology at its best – when I first started thinking about the trans-Arctic interchange – have to look at closely related taxa on multiple coasts, degree of replication you see nowhere else.

Steve Dudgeon …

David Wethey – larvae are being blown through the Cape Cod Canal; rock along the northwest of the Cape Cod canal
Anthony – this is a clear example, but is there a suite of other examples besides Panama also – where you see these ecological interactions?
Tom Trott[?]– What's Chthamalus' competitor?
David Wethey – *Semibalanus balanoides*
Paul – What is the relative importance of repeated exposure to sub-lethal temperatures vs. maximum?
David – lethal limit vs. coma limit
Paul – I was getting a bunch of mortality…
David – one would assume that if the animal was in this completely flaccid state, the predator –prey interactions would be …
Paul – Timing comes in to play in terms of life cycle of organism even if things go with rock temperature, water temp – it all comes down to mass.
David – Barnacles really track rock temperature, so largely influenced by rock temperature; mussels more purely influenced by air temperature because of the attachment to the rock.
Hawkins – biological interactions are important but are driven by biotic interactions - the interaction is driven by the temperature. *S. balanoides* – very rarely see
David – There are many layers of how these things conspire to set limits
Phil Williamson – temperature regulated distributions – I tested the idea by Jack Lewis [???] that young limpets were vulnerable to late frost, based on tide exposure during the night – had settlement plates brought in, put in freezer overnight – young limpets were resistant to frost hypothesis.

Rick Wahle – I am primarily interested in recruitment ecology in benthic species, I tend to walk that fence between basic research and the fisheries side of things. I work on lobsters and sea urchins and do some deep sea work with the red crab, but I'm very much interested in the processes operating both before and after larval settlement that influence their distributions and abundance. And that's really how I came to a broader interest in biogeography. My primary work with lobsters focuses on trying to develop predictive tools to predict things for the fishery. We use suction sampling, really focused on the cobble boulder habitat that's preferred habitat for settling lobsters. Have also been measuring the recruitment of lobsters, crabs, urchins, fish spp, algal spp. It was back in 1995-6 where I was working on another project over in Ireland and I noticed all these great cobble habitats on the west shore of Ireland and I got in the water to take same data on cobble habitat – I was interested to see how these habitats might be used by these communities in the eastern Atlantic. So what I did in 1994-5 as a preliminary dataset that only now with CORONA am I starting to take a look at – in Ireland, Channel Islands off France – I did some basic comparative ecology in terms of distributions – one of the provocative patterns that emerged you can see from the overhead – it's a genus and family list of the crustacean decapod taxa that we find in these cobble habitats – what struck us was we knew how depauperate the New England taxa were, but when you look at the European side, even though there's a fairly good fishery for *Homarus* their numbers were barely detectable in their cobble habitats. *Cancer* and *Homarus* were really the rarest of the decapod assemblage on the east side of the Atlantic (unlike the western Atlantic); instead it was dominated by xanthid crabs, galathiids, alphids, porcelanids, all of which are pretty fierce little competitors when defending shelter space. Perhaps the relative rarity of *Homarus* and *Cancer* on the European side may in fact be explained by competition… Also a much greater diversity of predators; so maybe species interactions in general, but what explains the absence or rarity of these other groups on the American side? It may be inability to colonize, but may be physiological – seasonal extremes are so great on the American side, so reasonable to think that physiological stress is a reason where these species are able to invade. I'm sort of now trying to carry this forward with a few other workers, both in Canada & the US and on the European side. Cliff asked for concrete plans; the plans are etched in jello at this point! We're trying to integrate the descriptive ecology and experimental macroecology, looking at the fate of cohorts through time. The phylogeography and history of *Homarus* would be an interesting route to take here. Some of the players on American side include Pete Lawton at Huntsman, in the EU: Per Moksnes[?] in Sweden, Oliver Tully in Ireland, and Juan Freir in Spain. In terms of systematics – Les Watling, Gerhard Poll in Canada, and then for genetic work – Prodohl (Ireland), Bucholz (Germany) working on efforts to work out genetic structure of *Homarus* populations. We have existing support for monitoring going on in New England from state support, NSF, NOAA, but also support form NSF to do more manipulative experiments over an incredible gradient from northern to southern New England to use these as a spring board to spawn some larger scale projects across the EU. Just to mention one program, there happens to a NOAA Irish program to foster collaborative projects, also EU Inter-reg – interregional comparisons.

Emmett – Do xanthids have higher distributions?

Rick – xanthids are also hardest to identify too, don't know whether they are…

Ladd – Because cobbles accumulate in certain hydrodynamic environments – it's a standardized habitat – makes it easy to predict, pick out sites?
Rick – Sure, mapped 150 km[?] of Maine/New England coast at a single depth to look at habitat.
Phil – Is it a difference in fishing pressure? Have the Irish caught all the lobster?
Rick – There aren't a lot of records there – at least right now, fishing pressure is huge on the North American side, definitely higher than Europe, and they still seem to be ecologically successful.
Cliff – They're different species, have been divided at least a million years – though that doesn't mean they aren't equivalent ecologically.
Rick – glacial refugia?

Steve Hawkins:

Elegant experiments…
A UK version of Cliff's CORONA vision. Project formerly known as BIOMICS…
Funding:
Have to be interdisciplinary and integrate different scientific approaches.
New name: REBECCA - REsponse of BEnthic biota to Climate change in Coastal Areas[?]
….now on to the subject of the hour…
I think there's been more listening, and now ideas half cocked last year are a bit more solidified.

Europe:
In Norway, seaweeds extend far out onto shores. Wales, south British Isles, patchy seaweeds mid shore, not as far out into exposure. Animal communities in the sheltered zone more. Spain and Portugal have very little seaweeds, a lot more animals, high diversity of grazers, limpets and trochids.
America:
See notes on diagram that they put up on wipeboard. X axis-absolute exposure (waves) Y axis- abundance.
Europe: distribution
After oil spill, dispersants killed grazers and shores had tons of algae, took 15 years to revert back. Herbivores are compressing algal range in parts of UK.
America: No *Patella*. So, expect switch between exposed and sheltered shore communities might be at higher absolute exposure level because grazers can't pick up the slack. We've been thinking about trying to do paired experiments that involve removal of algal canopies at a variety of absolute range of exposure conditions and removing grazers along that range as well. Key: how do you get absolute wave exposure? Usually base it on biological community, but problem is that the biology is mixed up in the interactions and we can't use the communities to clue us into physical parameters. Helmuth and Hillbish have helped us measure exposure. i.e. Strain gauge the size of little organisms, can measure wave exposure at size scale of the organisms in the community. So, can examine how colonization history has affected primary productivity patterns and diversity patterns on the western Atlantic coasts. Interplay between exposure, grazers, and community structure that we want to look at.

Canopy species: are equal on both sides (roughly).
Predators: also quite similar on both sides
Grazers: American assemblage is subset of what's in Europe.
Also, the European grazers have moved up from the south. Collision of northern boreal flora and fauna with chthalamid barnacles, limpets, trochids from the south.
In discussion on first day of this meeting, [??] said that the subcanopy species might be totally different on the two sides. UK-complex turf forming- *Corallina*, *Cladophora*, occur higher up under *Ascophyllum* canopies. America-not much of a sub canopy.

Cliff: Pattern noticed for a long time: species that tend to be trans-Atlantic also tend to be from the Pacific. Is there a simple answer to why the guys from the south don't make it over to the western side?
Steve: *Patella* got as far as the Faroes.
Cliff: Entire biotas have different propensities to establish in other areas.
Steve: Trans-Arctic ones have had to deal with it, whereas southern have estuarine refuges…
Tom Trott: REBECCA program – the NSF Biocomplexity program funded workshop of impacts of climate change on estuaries. Three papers almost done, should be published in Estuaries soon. Effects of sea level rise, freshwater flow, and ??? There is a movement to try to understand this in a broad way. Estuaries meeting is next month, that will have lots of discussion of these subjects.
Steve: By nature, estuaries are fragmented habitats, often don't occur on open shores with larger species pools.
Tom: Many marine organisms lived farther inland in not so distant past.
Steve: Estuarine species are a bit like high shore refugees. Can live lower down, but they've been pushed up…
Jerry Hilbish: Trans-Arctic migrants phyletically selected for high invasibility or wouldn't be in Atlantic in first place. Makes strong predictions about how barnacle/mussel associations will fragment: recruitment limited or not depending on exposure gradient.
Steve: Need to look at recruitment from banks of recruits from sheltered conditions, are there enough to swamp predators or penetrate algal canopy?
Jerry: If shifting into more protected regimes in Europe, might be greater continuity of barnacles along shore and more fragmentation of algae, and converse in America, and this might be interesting.
Steve: Along this axis, recruitment really important, affects probability of outcomes.

John Grahame – I'm the spokesperson for a group of four, maybe a group of six which is part of a group of nine! It's difficult to write a grant proposal at all to achieve coherence – and it's more difficult, too, when lots of people are talking to each other. We thought that we would come up with or try to focus on our understanding of what the CORONA ideas is about. What we've done is started with that and said what's our response to that, and we're trying to come up with something that might be fundable in the not too distant future. We should be able to not just detect and interpret these signals, I would lay a lot of emphasis on correct interpretation – if anything allows us to make

any kind of prognosis for the future, its direct interpretation that's important. Climate change is an opportunity as biologists to get money, attention and focus – and because we're evolutionary biologists, it's an intellectual challenge as well. List of tractable questions – response to thermal gradients, response to biotic impacts from competition or predators, phylogeography of organisms involved. List of possible taxa - Littorinidae, *Nucella, Mytilus*, fucoids, barnacles, *Gammarus*; maybe things are poster children for entirely different reasons, but maybe they chose them for entirely different reasons. Depending on who is involved as an investigator here is going to modify the choice of organisms. Methodology – survey – phylogeography on subtidal sequence data, parallel sampling over multiple spatial scales using gradients of latitude, coast/estuary, across tidal range (Is thermal gradient the most important driver here?) Many of these exercises feed into experiments in the lab, but we're focusing on field experiments. Finally a great strength here of the CORONA approach – if we are working in parallel on both our sets of coasts, then we are likely to come up with more properly interpretable data, which are stronger and much more scientifically valuable in every sense of the word and potentially useful as well. I ought to finish off with something that is my responsibility – CORONA is a big circle – a network about 50 strong right now; a very small network within CORONA has been discussing these ideas; we should all be setting up email networks within the CORONA network so we can keep people informed about people who are really thinking alike.

Tom – OK, you said be critical. Let's assume climate is the basic premise, and let's pretend I'm a grant reviewer and I get a grant to review and in the paragraph you listed several taxa that we've heard a lot about in the last few days.

Why those groups?

John – Parallelism – we're able to do parallelism on both sides of Atlantic

Emmett – most of the organisms that you mentioned are major community dominants, or engineers, etc. important ecologically

John – I want to move parallelism up front.

Andy – Still if you're trying to justify it in terms of climate it would be nice to say they respond to climate change. Has anyone done that?

John – Thermal gradients etc, I think it's implicitly in there.

Dave Rand – The thing that really strikes all of us is that the colonization of the Atlantic was driven by climate: bunch of clinal traits, high tide and low tide clines, surface temperature of water, etc. Parallel suites of adaptations to thermal stresses, we think temperature is the bogeyman we're all talking about here. Climate change, etc. is all related. Ecological community in the intertidal has to deal with this repeated pattern in organisms that are not phylogenetically closely related.

Jerry – In all studies of adaptation, if you have a correlation on broad geographic scales or repeated estuaries – if the response is replicated – then you really have something to explain. If you can add to that an experimental site, then you really have some adaptability.

Phil – My query is on the pragmatic side. Who is this a proposal to? We don't want to have parallelism to the point of duplicate proposals going to the same funding body

John – It's not a proposal at the moment, it's a framework around which we might seek funding.

Steve Dudgeon – What I want to talk about is a project I've been thinking about that falls under the CORONA umbrella because it's in accord with CORONA interests. It's a life history evolution question – how variant life cycles arise and are maintained in different environments. The importance of a temporal scale – both the beauty and challenge is that we have to think about incorporating temporal scales into ecological query. The flip side of what Brian said earlier – how can we incorporate historical time scales into what we see today?
Geographic parthenogenesis – pattern where asexual variant is always in more extreme environments, more resource-poor environments. It's best known in plants and there's an increasing number of apomictic plants with latitude; not just terrestrial but also marine. The problem with trees is they're too big; you can't move them around – no explanations are correlative. On the other hand, intertidal seaweeds are smaller than we are, and we can chip them off rocks and move them around; really good model systems to look at the mechanisms that underlie these patterns. There's a Joel Peck nature paper – these patterns can emerge from simple assumptions of organisms moving where they are more adapted.
Genus *Mastocarpus* – *Mastocarpus papillatus* has gametophytic and sporophytic stages. Dioecious gametophyes, syngametes, develop into sporophyte crust. Through meiosis they develop haplophyte spores which regenerate the gametophytes. There are also asexual forms that just recycle the 2N phase in frond forms. Distribution of species on Pacific coast span from Alaska to Baja (two species). Proportion that are apomictic in south is about 0, and it slowly increases to San Fancisco Bay where it dramatically increases, then it dramatically increases and remains high as it goes farther north. In the Atlantic, in Europe, you also see probability of apomixes which is low in eastern Atlantic in the south increases dramatically at English Channel. In western Atlantic, almost all apomictic, probably because all sand south of the Long Island, not a lot of opportunity for sexual plants down there. Hypotheses to explain parthenogenesis:
Present day processes – region-specific selection for each phase? Origin of asexuality in marginal habitats? Historical processes – glacially drive compression distribution followed by differential dispersal northward of life history variants during post-glacial sea-level rise? Interested in looking at relative reproductive outputs for the different phases, also doing reciprocal transplants up and down the coast. With much of the focus here being on focus, if there is a poster child for an affirmative action program in CORONA, *Mastocarpus* is the genus.
Geoff – This reminds me of freshwater *Daphnia* – facultative – is there anything you can identify that would parallel this?
Steve – Well, *Mastocarpus* is obligate, they never go back.
Howie – There is a fundamental change south of San Francisco – there is no freshwater input.
Steve – Just the formation and outflow of San Francisco Bay in the last 10 kya is another dispersal mechanism
Roger Hughes- *Wolbachia* causes this in *Daphnia*(?) parallel in algae?
Chris Maggs – No.
Hughes – Cyclostomes do it too, but devil of a time coming up with an explanation. Because there's no motile stages in the life history…..

Grant Pogson – PISCO intiative –

Integrating PISCO with CORONA…
Alcohol reference here to both PISCO and CORONA…
What is it? Partnership for the interdisciplinary studies of Coastal Oceans, primarily marine ecologists, but also oceanographers and evolutionary genetics types.
Who: Oregon State University-Lubmengo lab
UC Santa Cruz Raimondi and Mark Carr
Hopkins Marine Station: Somero and Denny
UC Santa Bartbara: Steve Gaines and Bob Warner
Mainly the three other than Hopkins
Funding: Packard foundation, 5 year, 24 million dollar grant, in 5th and final year (August 2004) applied for another round for another 5 years, its in the works
Objectives: long-term program that wouldn't finish in 5 years. Packard wants continuation for 10, 20 30 years.
Tied very closely to Hewlett Packard stock, so when dot.bomb happened, their revenue plummeted. So-don't know where they are, looking not as horrible as feared, but prospects are still up in the air.

Primary objectives:

1. to understand the processes and mechanisms underlying the dynamics of coastal ecosystems in the NE Pacific. Top down, bottom up, nearshore oceanographic, and more. Long enough time and big enough spatial scale. NSF won't fund that kind of time and space scale, but private foundation could and would.
2. to communicate relevant scientific information directly to the public and policy makers. Right now, big initiative to design reserves, PISCO playing major role in contributing information and facilitating the communication of that information.
3. initiate a novel program in interdisciplinary training and research.

Major research questions:

1. what are the major factors affecting community composition and what spatial and temporal scales do they operate on? Again, emphases on scale. 1500 km span. 16 main sites sampled 1-2x a year, essentially SWAT teams to sample. Who's there and where are they?
2. what are the spatial and temporal scales of marine larval dispersal? Species that have planktonic larvae with potential for substantial gene flow. Big attempt to get genetic info on resident adults and temporal recruitment of cohorts. I.e. mussels and rockfish. How far do larval plumes disperse?
3. what are the linkages between community dynamics and oceanographic processes? At each PISCO site, 3 stations, biological and physical oceanographers have instruments in water column, trying to track oceanographic conditions (3 places?). Trying to link oceanographic factors to recruitment and more.

How to integrate CORONA with PISCO?
How can ecological and genetic data from Pacific taxa provide insights on the historical ecology of the North Atlantic?

-Timing of invasions -not just opening up Bering Strait, more recent things going on
-Information on historical and contemporary gene flow-might shed light on troublesome data from Atlantic
-Insights into adaptation and speciation, especially speciation.

Rick Wahle: Doesn't seem like PISCO has historical component that CORONA does? Given rich fossil history in Pacific, any moves to incorporate?
Grant: next round of funding could involve. As it stands now, all short term ecological.
Cliff: I'm sure we're all impressed with ecological scope. Maybe we can replicate those efforts.
Ladd: what fraction of budget goes to labor for field crews.
Grant: a lot.
Ladd: what about oceanographic?
Grant: most effort is definitely in the labor the techs and the field crews. They've got thousands of Tuffies out there that they have to pick the larvae out of
Tom: why only going out 1-2x a year?
Grant: so many sites. 60. amazing species distribution info coming out of it. Around Monterey Bay, seems to be a major transition zone that's jumping out of data, and hasn't been looked at before or well described.
Brian: SWAT sites-50-60. Core sites-25, sampled every month. Another lesson to add: consistency between sites was plaguing, and so were individual PIs agendas.
Grant: also subtidal sites, up to 30 m deep.
Steve Dudgeon: Steve Gaines has been looking at some of these for longer. 9 cm upward shift into intertidal distribution, and that's happened for several species.
Grant: finding that frequently.
Cliff: Grant works on *Mytilus californianus* and generously didn't talk about that.

Ladd Johnson

Exotic species and biological invasions
I'd like to try to give you guys a perspective on this. Don't want to be a party pooper as in the map is getting all messed up with introductions, but just want to integrate all these things. Last meeting we had an invasions bubble, and no one came over to stand with me in that bubble, so I see it's an overwhelming interest….
Two major points:
Don't forget there are lots of movements of species that will change our interpretations of species ranges. I'm here as a classically trained experimental ecologist, and now I've been hijacked by invasive species work in freshwater.
Historical record meaning written history, our survey tradition didn't start until 150-200 years ago. Lots of human movement before that. I think it's exciting to use modern approaches to figure out where we might see species moved by human intervention.
Sample more haplotypes, keep it in mind. Species are probably native, species that are probably introduced, and cryptogenic, we can't tell. It's an opportunity to help answer basic biological questions-more on that in a minute.
Invasions aren't over-they are continuing today.
Ex's: Seaweeds- *Polysiphonia harveyi*

Chris Maggs studied in McIver?
Was considered along east coast as native range-1800s description. 1980s, found in British Isles (Chris Maggs). Realized that it actually was probably from Japan, and got collections from there and France. It had been in France since 1830s. There are 2 haplotypes. First haplotype, didn't know where it was first relative to North America or Europe, but it is Japanese, and so is second.
I use that as a way of illustrating my previous points.
Ongoing species invasions, or that we don't think were originally on both sides but now are, we can look at species interactions, behavioral responses, phenotypic plasticity. i.e. green crab invasion-been in Europe for forever. Now moving up St. Lawrence, probably several invasions contributing to presence on western side of Atlantic. For me, working on snails, looks like a wave of predators for them to respond to. There's a gradient along western Atlantic, can look at short term changes on western Atlantic along with evolutionary things in locations where it has been for longer.
I have been in contact with people in Canada to look at dispersal and community impacts of green crabs in the Gulf of St. Lawrence and Canadian maritimes. Iceland-are green crabs on south shore and none on east, that's exciting…
Dave: Are there invasives that have gone the other way (from American over to Europe)
Whole Room: *Mya arenaria*, *Spartina alterniflora*, others that I missed
Dave: are timings similar so parallels could be made?
Ladd: I've been trained with the standard burn 'em scrape 'em don't worry about exotics on Tatoosh-I don't have experience with marine invaders.
Steve: a more interesting question-any known species from a different biogeographic province that have invaded Europe and America and can we track responses on both sides given the different diversity?
Chinese mitten crabs in CA and Europe??
Hemigrapsis sanguinus??

Jon Witman:

We had an idea that came out of our discussion group yesterday morning, so I thought we'd float it and see what you think. Do oceanographic processes drive benthic assemblages of organisms (local)? We really don't know what spatial and temporal scales drive community dynamics. There are episodically huge recruitment events of marine animals and plants, notably mussels and barnacles. Massive settlements of mussels in the intertidal and subtidal zone have had a bottom up effect on the food web, and leave long-lasting signatures in the community dynamics. How to capture the scale and the temporal dynamics of these recruitment events?
Brief story about trends in percent cover of *M. edulis* in New England – If you've monitored recruitment or made some observations you know there were 2 big recruitment events in 1995 and 2000 – there seems to be some periodicity – 1995 was in both subtidal and intertidal in southern Gulf of Maine primarily; and the one in 2000 was captured from Long Island Sound to Portland, Maine. Basically the largest *Mytilus* settlement in 10-15 years, as long as anyone can remember. There's a paper coming out on the ecological consequences of this subtidal event. Imagine a rock the size of this room about 10-15 m down completely covered in *Mytilus* recruits! And this led to high populations of *Asterias* – a year later highest historical levels of *Asterias* in 15-16 years. After crabs and

Asterias, etc. removed their prey over a year, then *Asterias* developed density dependent cannibalism. So what caused these settlement events? Oceanographic drivers? Temperature shock? Intrusion of some water mass that caused spatially synchronous spawning over a greater scale than normal? Or is it correlated with intense phytoplankton blooms? Andy and I thought the following was exciting and frighteningly ambitious – we should start an intertidal sampling program on rocky shores, 6 times a year where we coordinate sampling form Long Island Sound to Newfoundland, and European events, and massive recruitment events and failures. These food web consequences are pretty general in marine ecosystems. Andrew was going to say something about possible correlation with North Atlantic Oscillation (NAO).

Andy Pershing

1995 and 2000 were both high NAO years, both 1996 and 2001 were both very low NAO years, but not diagnostic as other years were high. Following high NAO, you get a water mass coming in that is a degree or two warmer, also higher in nutrients.
Geoff – Is the graph recruitment or % cover?
Jon - % cover, but Millstone[?] have gone out and looked at larval supply and looked at density of ??? on shore [this was an overhead or drawing] – the 2000 was directly predicted by larval supply in water column. Need to quantify input level.
Look at headlands and bays, keep it simple; get some pilot data to show that it can be coordinated on both sides of the Atlantic, and potential advantage of the CORONA approach – maybe NAO is driving it – alternate in phase between eastern and western Atlantic? And only way to know that is to look at it across the Atlantic.

Roger Hughes – *Celleporella hyalina* – encrusting bryozoan on macroalgae, size of fingernail. Individual animal begins as a single larvae that settles hours after release, then starts to form a colony. Male zooids release sperm into seawater, are taken up into neighboring colonies, incubated 3 weeks and released as more larvae. Colonies survive several months before substrate decays out, or are grown over. In lab can grow them on acetate (overheads) can cut them in half when colony is big enough, and keep them going for years – some for 7 years so far. Classical taxonomists have recorded temperate Atlantic and Pacific as well as scattered upwelling regions – Morocco, Chile. Struck us as good model organism to look for sibling species to see if we can see how sibling species increase the biodiversity of what we normally think we see in the sea. Try to get samples from as many localities as possible. Three main things with these samples. Early on it was obvious we were finding distinct clades wherever we looked. Our job was too look to see if they were reproductively in compatible or not, and if we could see morphological differences – all reproductively in compatible, and subtle differences between them all. There is one interesting case where the reproductive trials have revealed a distinction that wasn't apparent form the genetics. The northeast Atlantic clade – the Icelandic individuals won't reproduce with the rest of the northeastern Atlantic species. Need to know something about distribution of macroalgal substrate – need to talk carefully with the paleobotanists.
Lunt – Cryptic species complex – mtDNA, nuclear genes; very divergent clades – rough molecular clock, they haven't been exchanging genes for 5-10 million years. Variation is

hierarchical – zoomed in on northeast Atlantic clade. Not all phylogeographic patterns will show glacially mediated patterns. Size of circles is how many individuals we've sampled, length of branch is distance. Originally we had a nice clear story and ruined it by additional sampling – was necessary – huge variability just between locations. Particularly between Scotland Orkneys and northwest Ireland. *Celleporella* is a beast that likes it cold. We don't really understand the barriers to its gene flow and how it's been substructured. Perhaps another one is that we're not really talking about refugia from the ice, because there's no evidence whatsoever that it's been through contraction and expansion. Quite likely that it really likes the glacial conditions – and perhaps during interglacial today it's in a contracted range. I'd really like to get feedback from people considering structure and diversity concerning either of those ideas. Either biological or geological ideas that we've missed, or the idea that we're seeing the interglacial restricted distribution.
Tom – When was the species described in the first place?
Roger – Linnaeus described it probably.
Tom – Did the prior people who studied the ecology have all the sampling you did?
Roger – Yes, they did.
Howie – Most different groups genetically are in northwest Spain. Can the two northwest Spain be sampled…
Lunt – They went extinct during the oil spill.
Emmett – Can they survive on hard substrate to give us a fossil record? Can you use that to get the geographic range?
Roger – Very difficult.
Howie – Do they look the same?
Roger – Slightly different.
Myriam – The microsatellite work – how does it compare?
Lunt – Roger's early work showed they were not moving around at all even in a small spatial scale in UK.
Steve – Quite a lot of species popping up in Spain – could come from different parts of northern Spain.
Rick – It occurs to me that it would be tremendously useful to have a picture of the planktonic availability across the Atlantic. Probably 99% of invasions are failures and probably have gone undetected. To get some sense of failed invasions we need to get idea of propagule availability on a huge scale.
Roger – What you need is occurrence of rafting on plastic or algal mats, you'll never get larvae.
Rick – Does the continuous plankton recorder get stuff?
Andy – It's a pretty coarse mesh – it picks up big stuff.
Jerry – Rudy Scheltema's old data?
Andy – Modeling study with high resolution distribution data in water column – and how might you expect them to go given their life history.