Window on the Sea Research Symposium

Abstracts

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1.1 Cod Broodstock Development: What's going on at the St. Andrews Biological Station and Huntsman Marine Science Centre?

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The Atlantic cod genomics and broodstock development project (CGP, www.codgene.ca) was initiated in 2005 to create two regional family-based selective breeding programs in New Brunswick/New Hampshire (NB/NH) and Newfoundland & Labrador (NL). Eighty full and half sibling families are presently being reared in three sea cages in New Brunswick (Cooke Aquaculture, Inc.) from the NB/NH program. These progeny were produced during the 2006 spawning season at the St. Andrews Biological Station and Great Bay Aquaculture, LLC. Seventy five additional families were produced during the 2007 spawning season from the NB/NH program and are presently being reared in tanks. Preliminary data analysis is encouraging and demonstrates the possibility for improvement of important commercial production traits for the developing cod aquaculture industry. While family rearing is presently performed at the St. Andrews Biological Station, this component is scheduled to move to the Huntsman Marine Science Centre for production in 2008. Construction is presently underway on the new marine hatchery and recirculation systems. Results from the family production, data analysis and facility construction will be presented.

1.2 Climate Change and Range Shifts of Northwest Atlantic Commercial Species

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We report the potential for shifts in range of 26 marine species as sea surface temperatures (SSTs) change with greenhouse warming. We targeted harvested species whose southernmost ranges end above 25°N. These include shellfish, finfish, and seaweeds, but also introduced and invasive species, as well as an important copepod prey. We used a bioclimate envelope approach, determining each species' "thermal habitat" from its geographical distribution with respect to satellite-derived data on SSTs. We then applied projected temperatures derived from four Atmosphere-Ocean General Circulation Models to predict future ranges. Our analyses show that all species will experience some distributional change and many with their southernmost extent near Cape Hatteras will experience retraction of range there. For some species a retracted distribution is expected within Canadian waters. Species with greatest change in range include capelin, Atlantic salmon, a species already listed as endangered, and serrated wrack, a seaweed. In addition to range alteration some species also will be threatened by expanding ranges of invasive predators: the Japanese shore crab and green crab. Our results also demonstrate the importance of using multiple models for predictions, as they showed greater variability than climate-forcing scenarios.

1.3 HMSC and NaGISA: A new partnership in a global initiative

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NaGISA (http://www.nagisa.coml.org/index.htm) is a world-wide collaborative effort, started in 2002, that is aimed at inventorying and monitoring coastal biodiversity. The project name stems from the Japanese word *nagisa*, referring to the narrow coastal zone where land meets the sea.The international headquarters of NaGISA are in Kyoto Japan, with regional centers currently organized in Kyoto Japan, Fairbanks USA, Pisa Italy, Caracas Venezuela, Mombasa Kenya, and in January 2007 an Atlantic Ocean (AO) office at the Huntsman Marine Science Centre (HMSC) in St. Andrews, NB (http://www.nagisa.coml.org/north_atlantic.htm).

As one of the first Census of Marine Life (CoML) field projects, NaGISA has taken an ambassadorial role linking CoML goals and local interests, encouraging international cooperation and capacity building in coastal monitoring and research. Inventorying and monitoring biodiversity are crucial tasks for identifying and clarifying activities that impact ecosystems. NaGISA will provide baseline data for long-term monitoring, and information needed to answer fundamental questions concerning changes in biodiversity with latitude and longitude. NaGISA plans to complete a habitat specific, qualitative survey of the world's ocean shores. Initiated in the Pacific, NaGISA activities have spread globally over the last 5 years. Implementation of the plan is through a simple, cost efficient, low-tech sampling protocol (http://www.nagisa.coml.org/Protocol.htm) that can be adopted by many research groups and countries, with the intent of promoting local community involvement. The ultimate goal is a series of well-distributed standard transects from the high inter-tidal zone to a depth of 20m covering the world, which can be repeated over a 50-year or greater time frame. The two target habitats are rocky bottom algal and soft bottom sea-grass communities, chosen for their global distribution, community complexity and the poor state of current knowledge. Data collected through the NaGISA project will be incorporated in the Census` Ocean Biogeography Information System (OBIS), an online global atlas for accessing, modeling and mapping marine biological data in geographic context.

The great strength of NaGISA is the meeting of CoML goals of global biodiversity coverage by locally vested interests around the world, while creating a standardized data matrix suitable for testing a wide range of ecological theories and solving practical problems. No other program has ever dealt with biodiversity information with such fine resolution at such a wide scale. Because of the large international and geographic scope of the program, NaGISA relies on regional offices to coordinate and implement activities. In its brief existence, the AO office has formed cross-border partnerships with Suffolk University (T. Trott), University of Southern Maine (L. Incze), the Bigelow Laboratory (P. Larsen), the Department of Fisheries and Oceans (P. Lawton), Acadia University (G. Gibson, A. Redden) and the University of New Brunswick (G. Saunders). With the participation of G. Pohle and L. Van Guelpen at HMSC, and R. Rigby of NaGISA in Japan, field work will begin at three sites during the summer of 2007 with the aforementioned partners. There is no direct AO office partner funding but it assists in networking, identifying and leveraging sources for activities.

1.4 Sex Control in Shortnose Sturgeon (*Acipenser brevirostrum*)

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As a potential source of high value caviar, the commercial culture of sturgeon would benefit greatly from strategies designed to increase the proportion of females in cultured populations. This research investigated two methods – one genetic and the other endocrine – for manipulating sex ratios in the shortnose sturgeon, a native species currently being developed for aquaculture in New Brunswick. Gynogenetic individuals, carrying only maternally derived chromosomes, were produced by treating sperm with UV radiation and then pressure treating eggs shortly after activation with the irradiated sperm to prevent extrusion of the second polar body. From a sample of 100 putative gynogens, 96 were confirmed as diploid gynogens by a combination of flow cytometry and microsatellite DNA analysis. A sex ratio among the gynogens of 35% male and 65% female clearly indicates that female shortnose sturgeon are not homogametic, but the precise mechanism for sex determination remains unknown. Feminization of a mixed sex population of sturgeon was achieved by adding 17β-estradiol (E_2) to the diet at 0 (control), 10, 25, 50 or 100 mg/kg feed. As hormone dose increased the fish ate less and were less active, their growth rate was reduced and the incidence of organ pathologies increased. However, all E_2-treated fish were developing as females, based on anatomical differentiation of their gonads, compared to 57-65% females in control populations.

1.5 Spatial overlap and biotic interactions between sub-adult American lobsters, *Homarus americanus*, and the invasive European green crab *Carcinus maenas*

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Biological invasions are considered a major threat to natural populations and communities. In this study, we evaluate the spatial overlap between the invasive European green crab, *Carcinus maenas*, and sub-adult lobsters, *Homarus americanus*, in a lobster nursery area in Passamaquoddy Bay, New Brunswick, Canada. We also conduct two laboratory studies to investigate the biotic interactions between green crab and sub-adult lobsters; the first is a 62-d experiment to determine if green crabs (CW 33-70 mm) affect survival,

growth, and behaviour of similar mass sub-adult lobsters (CL 15-48 mm), and the second is a 7-d experiment to determine if very large green crabs (CW 53-78 mm) affect the survival of sub-adult lobsters. While there was considerable spatial overlap between these species in nature, particularly between 0 m and 2-3 m below chart datum, green crabs did not negatively affect survival, growth, activity, feeding, or sheltering behaviour of sub-adult lobsters in the laboratory. In fact, sub-adult lobsters regularly prey upon green crabs in the two laboratory experiments. Our results suggest that green crabs represent no immediate threat to sub-adult lobsters. We discuss the marked discrepancy between our results and those of two recent studies, and we outline areas of investigation that need be pursued in the future to generate a more comprehensive picture of the ecological interaction between these species.

1.6 Global Controls on Carbonate Preservation: Implications for the Skeletal Record and the Carbon Cycle

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Skeletal carbonate is our primary source of paleo-biological information, and the primary means by which carbon is transferred from the atmosphere-ocean to the lithosphere. As such, processes which control its preservation and fidelity (i.e. taphonomy) are of primary importance to interpreting the fossil record and the carbon cycle. My research quantifies taphonomic processes and potential preservation biases at scales ranging from within individual environments to across latitudes, with a focus on coastal settings as the main locus of global elemental exchange and anthropogenic impact. Over the past 15 years samples and data from tropical, temperate, and now polar locations have been collected to form the foundation for these latitudinal comparisons. Ongoing research includes short-term changes in macrotidal settings, and death assemblages and experiments from the Arctic (site of rapid environmental change and ice-scouring). Also, time-series experimental data will be obtained through the VENUS sub-sea observatory system in order to more closely track the nature and episodicity of taphonomic processes. Megabias, along latitudes or other environmental gradients, has significant implications for how we interpret changes in biodiversity, for example during past climate changes, with a view of forecasting biotic response to future changes. It also is key to assembling a global model of carbonate burial in shelf environments, currently poorly constrained but estimated to control half of the total carbonate burial, the main carbon sink of the carbon cycle.

1.7 The Huntsman experience: parasites I have known and loved

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Since the early days of Huntsman's creation, under the visionary, capable and guiding hand of Dr John M.Anderson in 1969, UNB has been closely associated with what was the Huntsman Marine Laboratory and what is now the Huntsman Marine Science Centre. A large number of contributions to our understanding of parasites, and how they affect their marine hosts, has been made by students and colleagues in the Parasitology Lab at UNB Fredericton, using the facilities at Huntsman and cooperating with scientists working in SABS, DFO. These include: **(1)** Identification of the 'oyster gill worm' (as *Urastoma cyprinae*), its unusual mitochondrial lens, and the special piquancy that these microturbellarians lend to the consumption of raw oysters on the half-shell; **(2)** Another parasitic turbellarian, *Paravortex cardii*, which lives in the gut of its molluscan host and produces up to 20 sets of twin embryos. As these grow, their "pregnant mother" (the adults are hermaphrodites) gets bigger and bigger until "she" bursts releasing all the babies ("In death, there is life!"); **(3)** *Cryptocotyle lingua*, a digenean which lives as an adult in seagulls. The life cycle includes early larval stages in periwinkles and when the temperature warms up to 11˚C, the cercariae emerge, penetrate the skin of passing fishes, and cause 'black spot disease'. Like *U. cyprina*, these also add a touch of "*Je ne sais qua"* when consumed on the top of periwinkle pizza or boiled and dipped in vinegar; **(4)** The plerocercoid larva of *Schistocephalus solidus* lives in sticlebacks, altering their behaviour so that they swim at the surface of their pond and making them easy prey to gulls in which the adult worm lives; **(5)** The seal worm, *Pseudoterranova decipiens*, and the whale worm *Anisakis simplex* are found in large numbers in the stomachs of seals and cetaceans which no-one seems to worry about. However, these mammals get infected by eating fish (especially common in cod and herring respectively) which carry the infective larval stages. Unless the fish is properly cooked prior to human consumption (or deep frozen for 3 days at -20˚C), worms that are eaten try to get out of the stomach, sideways, causing ulcers (frequently diagnosed in Japan as stomach cancer). The above examples as well as many more beautiful parasites, have kept the author, over 50 of his students, and several colleagues "happy in their work" at Huntsman for the last 37 years.

2. POSTER PRESENTATIONS

2.1 Seasonal and regional variation in the nearshore fish assemblage of the southwest Bay of Fundy

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Estuaries and associated coastal waters are regions of high productivity that serve as nursery grounds for several marine fishes as well as migration corridors for anadromous species spawning in freshwaters. Our research examined how the scale and structure of the nearshore fish assemblages varies 1) seasonally, by sampling six sites every two weeks throughout the year, as well as 2) regionally, by sampling 16 sites throughout the southwest Bay of Fundy over one week. A total of 18 species were collected throughout the year, which largely consisted of juvenile fishes with seven species making up over 95% of the total catch. Species richness and abundance were correlated with temperature, there being distinct warm and cold water assemblages present. More structurally complex substrates also yielded the greatest richness and abundance. Overall the nearshore assemblage of the southwest Bay of Fundy was typical of coastal regions of the mid Northwest Atlantic being dominated by few species and having a comparable richness to previous work using similar gears. The area was largely utilized as a nursery and included several commercial species. The dynamic nature of this region and lack of residency among many of its juvenile inhabitants limits the number of suitable (sentinel) species that can serve as indicators of environmental health.

2.2 Scallop eye numbers: an evolutionary response to predation?

K. Whoriskey, S. Whoriskey and F. G. Whoriskey

We quantified eye numbers on the mantles of sea scallops (*P. magellanicus*) to determine if the eye numbers varied with scallop size/age, and to compare the number of eyes present on the upper and lower mantles. Consistent with predictions of an adaptive evolutionary response in eye numbers driven by predation, we found scallops developed about 30% more eyes on the upper mantle where they could detect predators quicker and at larger distances, than on the lower mantle. However, contrary to our prediction, the smaller more vulnerable sizes of scallops did not have more eyes than larger scallops. Instead, we detected a statistically significant increasing trend in eye number with scallop size due to the addition of more eyes on the upper mantle. This contradicted our expectation that there would be attrition

2.3 Can we develop molecular diagnostics to identify parasitic threats (*Loma morhuae*) to aquacultured cod?

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Xenomas and spores, that were morphologically comparable with those of *Loma* spp., were found in tissues from each of 19 cod (*Gadus morhua*) sampled from two different aquaculture sites in the Bay of Fundy. In order to identify these to species, a sensitive and specific test (using a polymerase chain reaction [PCR] assay) is being developed for the detection of *Loma morhuae* rDNA. The rDNA of *L. morhuae* will be amplified using microsporidian-specific primers. The amplified fragments of rDNA will be sequenced completely on both strands and compared to other *Loma* spp. to discern areas with high variability in nucleotide composition. The variability in nucleotide composition between other *Loma* spp. will enable us to design a species-specific primer set that amplifies only *L. morhuae* rDNA. Infections with this parasite represent a physiological stressor that contributes to impaired growth, fish mortality, and hence financial losses during the grow-out phase. Early and accurate identification of this parasite is essential in developing both curative and prophylactic treatments in order to diminish or obviate disease outbreaks, facilitated due to high stocking densities that are maintained in sea cages. This technology will also facilitate an improved understanding of the epidemiology of infections through its use as a tool to elucidate the life cycle of *L. morhuae* and determine modes of transmission of this pathogenic parasite.

2.4 The flame cell enigma: evolutionary implications

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Relatively recent work in our laboratory has focused on the ontogeny of larval cestodes in relation to Janicki's Cercomer Theory. It is clear that there are two major groups: oviparous cestodes, which are considered to be more ancestral, and vivparous cestodes, which are considered to be more derived. The oviparous species typically are found in the ancestral Orders Caryophyllidea and Pseudophyllidea; the vivparous species are found in the more derived Orders Proteocephala, Tetraphyllidea and Cyclophyllidea.. We believe that the tapeworms evolved from free-living playhelmiths in fresh water, required in the life cycle of most, though not all, oviparous forms. The ability to osmoregulate in such a hypotonic environment is clearly important and it is, accordingly, not surprising to find flame cells in the free-swimming coracidia of species that use fresh water invertebrates as their intermediate host (e.g. *Diphyllobothrium dendriticum*). Whether such flame cells are also found in the free-swimming coracidia of species infecting marine invertebrates, is important to know in the context of their ontogeny and evolution.

A pseudophyllidean infecting a marine definitive host is *Bothriocephalus scorpii* in the sea raven *Hemitripterus americanus*. The coracidia of this cestode hatch in sea water and are free-swimming prior to being eaten by the copepod, first intermediate host. Examination of these newly-hatched coracidia suggested the presence of flame cells, which increased their "flickering" activity, if the coracidia were placed in fresh water. To confirm the presence of flame cells, similar to those found in free-swimming coracidia in fresh water, newly-hatched coracidia of *B. scorpii* were fixed and examined using transmission electron microscopy (TEM). Results confirmed the presence of at least one (probably two) flame cell(s) with 11 cilia as seen in cross-section. This finding is evidence of the conservative nature of early ontogenetic characters which are retained even with the evolution of the adult from a fresh-water host to a marine host.

2.5 Parasites of wild cod: threats to cod aquaculture

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The Atlantic cod, *Gadus* morhua, has evolved to survive in an environment with little temperature variation and almost no light. Any deviation from these abiotic factors could interfere with their physiological balance, or homeostasis. Any stimulus or factor which interferes with this homeostasis is called a stressor and as all stressors act via a similar physiological pathway, their effects are cumulative. Stressors result in the use of energy reserves (impaired growth), they induce immunosuppressive effects, and increase susceptibility to natural pathogens and parasites from the ocean environment. In addition to the various abiotic stressors, pathogens and parasites themselves are stressors which further contribute to impaired growth and increased mortality. This is important to the aquaculture industry because the high stocking densities (also a stressor), maintained in marine cage sites, lead to an environment that has the potential for major disease and parasite outbreaks. We have identified three parasites, commonly found in wild gadoids in Passamaquoddy Bay, which we believe are potential pathogens of cage-reared cod. These are: (1) *Loma morhuae*, a microsporidean, which can reach epidemic proprtions among aquacultured fish causing impaired growth, increased susceptibility to other pathogenic organisms, and eventual death; (2) *Gyrodactlus* spp. which are emerging pathogens in caged cod in Norwegian waters, with similar effects as *L. morhuae;* and (3) *Trichodina murmanica*, a small ciliated protozoan which feeds on the mucus of the host skin, allowing secondary infection of viral, bacterial, and fungal pathogens to become establshed. Future plans are being developed to mitigate the adverse effects of these and other potential pathogenic parasites.

2.6 Can Mummichugs and Killifish Share the Same Parasites?

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Fundulus diaphanus (killifish) and *Fundulus heteroclitus* (mommichogs) are two sympatric fish species, sometimes found in a shared habitat. Although *F. diaphanus* is usually found in fresh water, and *F. heteroclitus* is usually found in salty or brackish water, they may occur together giving rise to the possibility of hybrids. Each species has specific parasites that are generally found on or in them. This leads to the question of whether the parasite infection is specific to the environmental conditions in which the host is found or specific to the host species. If they are location specific, these two species sharing the same habitat

may also share the same parasites. As hybrids of these two species have been reported, investigating the parasites of the hybrid species may lead to further understanding of host versus location specificity of the parasites.
In our study, the parasites found so far were typical of those found infecting *F. diaphanus*, which we collected only in fresh water, or those found infecting *F. heteroclitus,* which we collected only from salt water. Had both species been collected from the same site, results may have differed. There are two locations in S.W.New Brunswick (Sam Orr's Pond and Slaughterhouse Ponds) where both species have been reported together. Future work will focus on parasites from both fundulids from these sites. In our collections, to date, hybrid species were not found. Accordingly, the question of parasite infection of the hybrids is still unknown. It would be of interest to study this further to gain a better understanding of the relationship between location, host, and parasite infection, and possibly to see evolution in progress in the form of hybridization, not only of the fish species involved, but perhaps also of their parasite fauna.

2.7 Contrasting Taphonomic Regimes Within Temperate Latitudes: Preservation of Skeletal Carbonate in Macrotidal Environments

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Post-mortem processes distort skeletal death assemblages, affecting our interpretation of the fossil record and our estimates of carbonate burial within the carbon cycle. The depositional environment influences net skeletal condition prior to lithification. A compilation of rates of shell weight change across 3 latitude zones (Best et al. 2006, unpublished data) suggests that much of the pre-lithification condition of skeletal carbonate is determined during the first year post-mortem. The results show that rates of shell weight change decline within a year in temperate environments. Information is missing for the first 6 months post-mortem when skeletal carbonate is most affected by taphonomic (preservational) processes. A detailed description and comparison of early taphonomic regimes within the temperate latitude zone will be an important contribution to the field of marine taphonomy. 3 intertidal settings in the Bay of Fundy, NB (sandy, exposed tidal flat; muddy estuarine tidal flat; salt marsh ponds with and without vascular plants) will be compared to their subtidal counterparts, and results calibrated using continuous experimental observations from Saanich Inlet, BC (VENUS), and end member low pH sites in Sudbury, Ontario Sites were selected along axes of water energy, pH, carbonate saturation, organic matter and biological regimes. The study involves: 1) macroscopic/microscopic analyses of *Mytilus edulis* and aragonite/calcite crystals experimentally deployed above, at and below the sediment-water interface; 2) macroscopic analysis of death assemblage; 3) pore water/sediment analyses. Preliminary death assemblage results (fragmentation and fine scale surface alteration) and experimental weight change rates show significant taphonomic differences within the same New Brunswick setting.

2.8 Experimental Assessment of Early Diagenetic Changes in Marine Bivalve Shells

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Marine shells are widely used in geological studies as ecological and chemical environmental proxies. In order to use their fossils for environmental reconstruction, it is necessary to understand the influences of early diagenesis on shell materials, including changes in morphology, microstructure, and chemical composition. To clearly identify changes from their initial state, fresh cultured bivalves (Mytilus edulis) were used in our experiments. We deployed one valve in the natural environment and kept the other valve in the laboratory as a control. These controlled experiments were done in at St. Andrews, New Brunswick, Canada; and Panama and Barbados, Caribbean Sea. After 9 days, 8 months and 1 year, the retrieved shells showed significant weight loss, varying among the different environments and with duration of deployment. Biological influences were found on the shells deposited at sediment-water interface: borings, encrustations at macro level, and microborings, biofilms, microbes at micro level. Modifications of the inner aragonitic nacre layer documented by SEM included: a) organic matrix loss between nacre tablets and lamellae, b) indentations along the edges of nacre tablets caused by dissolution, and c) inorganic precipitation of small CaCO3 crystals or overgrowth of nacre tablets on the surface of some shells deployed in tropical mixed carbonate-siliciclastic sediments.

After surface and microstructural study, the nacre layer was ground to powder for isotopic analysis. Carbon and oxygen isotopes were analyzed by a high precision system (<0.02‰). Bulk differences of up to 0.4‰ had developed among experimental and control valves within 1 year. These differences exceeded the variation observed between two valves of fresh shell pairs (<0.1‰). The possible mechanisms for isotopic shifts supported by SEM observations include partial dissolution of isotopically zoned shell carbonate and inorganic calcium carbonate reprecipitation. Results therefore indicate that early diagenesis can start very quickly after shell death and cause macroscopic, microstructural, and isotopic value changes in shell materials, but the nature of these changes varies with burial environment and they do not affect the nacre layer uniformly over its entire area.