

Krill Biology and Ecology Workshop

by William Peterson, Jaime Gómez-Gutiérrez, Angus Atkinson and Bettina Meyer

The final official gathering of the international GLOBEC scientific community was held from June 22–26, 2009, in Victoria, British Columbia, Canada, at the Victoria Conference Centre, a venue well known to most PICES scientists. The five-day meeting included 10 workshops on the first two days followed by three days of invited and contributed talks and posters. This report summarizes activities at the two-day workshop on “*Krill Biology and Ecology in the World’s Oceans*” co-convened by the authors of this article.

The idea for this workshop originated at a workshop with a similar title that was held at the PICES/ICES/GLOBEC 4th Zooplankton Production Symposium in May 2007, in Hiroshima (Japan). More than 100 krill enthusiasts at this workshop endorsed the need to meet more regularly, thus

Drs. So Kawaguchi and Bill Peterson proposed to GLOBEC that another workshop be held at the 3rd and final GLOBEC Open Science Meeting. The proposal was approved and planning began in earnest. The Victoria workshop marked the sixth time that krill biologists had assembled for the specific purpose of discussing krill biology and ecology, with the first two being held in Wilmington (North Carolina, U.S.A.) and Bremerhaven (Germany) in 1982 and 1983. After a long pause, regular gatherings took place with the third and fourth meetings in Santa Cruz (California, U.S.A.) in 1999 and Nagoya (Japan) in 2002. The Hiroshima meeting was the fifth. Discussions are underway to propose a seventh meeting in Pucon (Chile) as part of the forthcoming PICES/ICES 5th Zooplankton Production Symposium to be convened in 2011.



Krill Biology and Ecology Workshop in session.

The purpose of the krill workshop was fourfold. Firstly, the conveners recognized the need for those working on different euphausiid species to get together to discuss methods/approaches that have proved effective for one species to see if they could be applied to other euphausiid species. Secondly, we wanted to make sure that there was a degree of harmony (or at least that there was no serious disconnect) in research approaches, recognizing the need to improve technical aspects of specific methods where necessary. Thirdly, we wanted to generate ideas for future collaborations (laboratory/seagoing exchanges of personnel and exchange and pooling of datasets to address broad-scale issues). Finally, we proposed to produce a tangible product, to show where krill research is at the moment, and to identify hurdles to progress and potential solutions. It was agreed that “the krill workshop group” will produce a summary paper for consideration of publication in the *Marine Ecology Progress Series*.

Towards these ends, on the first day (June 22), 16 presentations were made which summarized national programs – nine talks on work in the Antarctic mostly focused on the Antarctic krill *Euphausia superba* by scientists from the UK, Germany, Australia, Korea and the

USA and seven talks on work carried out in the Pacific (in Peru/Chile, Mexico, USA, Canada, Japan, China and Korea). At least five common themes emerged from the discussions:

1. The biomass of all krill species has likely been underestimated, and thus there is a need to make better use of acoustics and large plankton nets in order to derive proper estimates of krill biomass;
2. We need to gain a better appreciation of the role of krill as predators and prey in marine food webs, especially with regards to krill as a “wasp-waist” species (*e.g.*, *Euphausia superba*, *E. pacifica* and *Meganyctiphanes norvegica*) – by definition, such species occupy an intermediate trophic level that is strongly dominated by a single species with large fluctuations in biomass such that their prey and predators are measurably impacted by the large swings in biomass;
3. We only have a very rudimentary knowledge of krill behavior and the factors which result in krill forming schools, aggregations and patches at multiple time–space scales and their role in energy cost, physiological adaptation mechanisms to a strong seasonal environment such as the Southern Ocean, species condition and parasite transmission;

4. We need much more pan-oceanic research which will allow us to work out the impact of climate variability and change on krill ecology and production at different latitudinal ecosystems – on this topic, there is abundant evidence that the Antarctic waters are warming and that the ice sheet is melting, two processes that are certain to impact krill but in ways that we can only guess; and
5. Vast improvements have been made using IBM models linked with ROMS (Regional Ocean Modelling System) to gain a better understanding of krill population dynamics and of how eggs of broadcast spawning species and larvae are transported as a result of interaction of currents with ontogenic variations in vertical distributions.

Talks were supplemented by 17 posters that summarized topics such as larval development and growth, maturation, secondary production, parasitism, analysis of exploitation strategies, effect of global warming, grazing rates, variations in digestive enzymes, lipid trophic markers and larval drift modeling in different regions in the Southern Ocean and Pacific Ocean.

The second day (June 23) included talks on four hot topics such as novel uses of bottom-mounted upward-facing echosounders and high-speed video systems to study krill behavior and hydrodynamics of swimming and krill patchiness, estimation of mortality rates of *Euphausia pacifica*, and a comparison of the role of krill as prey in the Antarctic and North Pacific ecosystems. The remainder of this day was devoted to discussions of the structure of a synthesis paper that will be prepared for the *Marine*

Ecology Progress Series. This will be one tangible output from the workshop in which we will introduce krill as a “wasp-waist” species in important productive ecosystems around the world. The paper will highlight recent developments and issues in krill biology, improving our understanding of how this group fits into their ecosystems.

Perhaps 50 people from at least 11 nations attended the workshop for the two full days whereas another 50 attended one or more of the talks on the first day. Members of the PICES Working Group on *Comparative Ecology of Krill in Coastal and Oceanic Waters around the Pacific Rim* were well represented by talks by Bill Peterson, Dave Mackas, Yuji Okazaki, Song Sun, Hyoung Chul Shin, Leah Feinberg and Jarrod Santora.

The workshop was concluded with a power point presentation prepared by Dr. Jaime Gómez-Gutiérrez which honored the life-time achievements of three distinguished krill biologists, Edward Brinton and Margaret Knight (from Scripps Institution of Oceanography) and John Mauchline (from the Scottish Association of Marine Science, Oban, Dunstaffnage Laboratory). Each received a “commemorative diploma”, a copy of a krill video and a fetching krill “paper weight” made by Lisa Roberts (see below). Each of these scientists was a pioneer in early work on krill: Ed Brinton for work on zoogeography, taxonomy and ecology of krill throughout the Pacific Ocean; Margaret Knight for work on krill larvae taxonomy, including descriptions of the larvae of 13 euphausiid species, and John Mauchline for his research and periodic landmark reviews in *Advances in*



Three legends in their young careers studying euphausiids: Left: Edward Brinton at Scripps working on his Ph.D. research; Center: Historic picture of seven distinguished krill biologist in the early 1970s, from left to right A.C. Baker, Brian Boden, Tarsicio Antezana, Elizabeth Kampa, Edward Brinton, K. Gopalakrishnan, and John Mauchline at San Diego California; Right: Margaret Knight working at Scripps Institution Oceanography. Photos provided by Margaret Knight, Tets Matsui, Annie Townsend, Elizabeth Venrick, and SIO Publications.



Edward Brinton setting up a MOCNESS net in the Southern Ocean (circa 1991), Margaret Knight and John Mauchline (recent pictures). Photos provided by SIO Publications, Margaret Knight, and Glen Claxton.

Marine Biology on the biology and ecology of krill worldwide, still considered core texts of euphausiid biology. Tarsicio Antezana (Chile) had the original idea to do this tribute and wrote an informal, sometimes humorous, poetic text to remember the legacy of Ed and Margaret. Unfortunately our friend Tarsicio was unable to attend the workshop.

The workshop included some outreach materials produced by Lisa Roberts, a Ph.D. student from College of Fine Arts, University of New South Wales, who produced both our “krill logo” and an animation named *Antarctic Energies* which was shown during the workshop breaks and during the poster session. Lisa’s delightful and fascinating videos can be viewed at <http://www.antarcticanimation.com/content/animation/energies/energies.php>. The video *Antarctic Energies* was inspired by Lisa after she traveled to the Southern Ocean on board the R/V *Aurora Australis* and saw schooling krill alive in the Australian Antarctic Division Krill Laboratory in Tasmania and heard the insights of scientists who breed them. *Antarctic Energies* represents physical and biological forces that interact to shape Antarctica: diatoms, krill, sea butterflies (pteropods),

seals, albatrosses, humans, sea ice, bottom water circulation, the circumpolar current, ice melting, and sea level rising. Feel free to contact her (lisa@lisaroberts.com.au) or see her webpage at <http://www.lisaroberts.com.au/>.



A “krill logo” designed by Lisa Roberts.

An evening social at the Irish Times pub was attended by about 50 krill biologists and ecologists, where any krill stories were exchanged by all, but most importantly, new, exciting and fruitful collaborations were established. Without a doubt, these two days were truly an unforgettable bonding experience for everyone.



Dr. William (Bill) Peterson (bill.peterson@noaa.gov) is an oceanographer and zooplankton ecologist at the Hatfield Marine Science Center in Newport, Oregon. He works for NOAA’s National Marine Fisheries Service, and his research focuses on climate effects on zooplankton, particularly euphausiids and copepods. Recently his lab has made advances in the business of forecasting the return rates of salmon to their natal streams one year in advance. Within PICES, Bill has served on several expert groups and is currently a member of the Biological Oceanography Committee and Co-Chairman of the Working Group on Comparative Ecology of Krill in Coastal and Oceanic Waters around the Pacific Rim.

Dr. Jaime Gómez-Gutiérrez (jagomezg@ipn.mx) is a biological oceanographer at Centro Interdisciplinario de Ciencias Marinas (Instituto Politécnico Nacional) at La Paz B.C.S., Mexico. His research focuses on the biology and ecology of zooplankton and micronekton in the epipelagic ecosystem, particularly the study, since 1990, of euphausiid diel vertical distribution with hydroacoustic and submarine video cameras, secondary productivity, ecophysiology, and parasitism. He was one of the 15 authors of the PICES Science Report No. 30 entitled: *Micronekton of the North Pacific*. During 2008–2009 he did a sabbatical research at the Australian Antarctic Division at Kingston, Tasmania, working on a review of euphausiid parasites with Steve Nicol and So Kawaguchi. He did a Ph.D. thesis at Oregon State University working in several GLOBEC research projects studying euphausiid embryonic development rates, hatching mechanisms, reproductive effort, and parasitism of *Euphausia pacifica* and *Thysanoessa spinifera* along the Washington–Oregon–California coasts.

Dr. Angus Atkinson (aat@bas.ac.uk) works at the British Antarctic Survey in Cambridge, UK. He is fond of all kinds of invertebrates (even terrestrial ones – see photo), but his real love is Antarctic krill. He started working on krill by accident in 1996 (there were not any amphipods to work on but loads of krill instead) and has worked on them ever since. Topics include feeding, excretion, defecation and growth, and more recently large-scale distribution. All of this involves a healthy amount of laboratory work and experimentation on live animals, and Angus has now participated in 15 Antarctic cruises.

Dr. Bettina Meyer (bettina.meyer@awi.de) is a marine biologist at the Alfred-Wegener Institute of Polar and Marine Research (AWI, Germany). She worked on trophic interactions and the seasonal variability in ecophysiological conditions on planktonic crustaceans. Since 1999 her research focuses on the physiology of Antarctic krill, the mechanisms causing synchronization between the seasonal development of krill and the seasonal cycles of environmental features in particular. She has been initiated the LAKRIS project (Lazarev Sea Krill Study), the German contribution to the Southern Ocean GLOBEC program.