THE RESPONSE OF ECHINODERMS TO OCEAN ACIDIFICATION
**The Response of Echinoderms to Ocean Warming**

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As the air’s CO₂ content rises in response to ever-increasing anthropogenic CO₂ emissions, and as more and more carbon dioxide therefore dissolves in the surface waters of the world’s oceans, theoretical reasoning suggests the pH values of the planet’s oceanic waters should be gradually dropping. The IPCC and others postulate that this chain of events, commonly referred to as ocean acidification, will cause great harm -- and possibly death -- to marine life in the decades and centuries to come. However, as ever more pertinent evidence accumulates, a much more optimistic viewpoint is emerging. This summary examines the topic of the potential impacts of ocean acidification on echinoderms.

According to Dupont et al. (2010), “echinoderms are among the most abundant and ecologically successful groups of marine animals (Micael et al., 2009), and are one of the key marine groups most likely to be impacted by predicted climate change events,” presumably because “the larvae and/or adults of many species from this phylum form skeletal rods, plates, test, teeth, and spines from an amorphous calcite crystal precursor, magnesium calcite, which is 30 times more soluble than normal calcite (Politi et al., 2004),” and this fact would normally be thought to make it much more difficult for them (relative to most other calcifying organisms) to produce calcification-dependent body parts.

Working with naturally-fertilized eggs of the common sea star *Crossaster papposus*, which they collected and transferred to five-liter culture aquariums filled with filtered seawater (a third of which was replaced every four days), Dupont et al. thus tested this hypothesis by regulating the pH of the tanks to values of either 8.1 or 7.7 by adjusting environmental CO₂ levels to either 372 ppm or 930 ppm, during which time they documented settlement success as the percentage of initially free-swimming larvae that affixed themselves to the aquarium walls, larval length at various time intervals, and degree of calcification. In doing so the three researchers report that just the opposite of what is often predicted actually happened, as the echinoderm larvae and juveniles were “positively impacted by ocean acidification.” More specifically, they found that “larvae and juveniles raised at low pH grow and develop faster, with no negative effect on survival or skeletogenesis.

In fact, they state that the sea stars’ growth rates were “two times higher” in the acidified seawater; and they remark that “*C. papposus* seem to be not only more than simply resistant to ocean acidification, but are also performing better.”

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1 [http://www.co2science.org/articles/V13/N34/B3.php](http://www.co2science.org/articles/V13/N34/B3.php)
within the time frame of the experiment (38 days).” In fact, they state that the sea stars’ growth rates were “two times higher” in the acidified seawater; and they remark that “C. papposus seem to be not only more than simply resistant to ocean acidification, but are also performing better.”

The Swedish scientists conclude that “in the future ocean, the direct impact of ocean acidification on growth and development potentially will produce an increase in C. papposus reproductive success,” and that “a decrease in developmental time will be associated with a shorter pelagic period with a higher proportion of eggs reaching settlement,” leading the sea stars to become “better competitors in an unpredictable environment.” Such favorable findings are surprising, especially for a creature that makes its skeletal rods, plates, test, teeth, and spines from a substance that is 30 times more soluble than normal calcite.

Schram et al. (2011) investigated the impacts of ocean acidification on another sea star, Luidia clathrata. In their experiment, “two groups of sea stars, each with two arms excised, were maintained on a formulated diet in seawater bubbled with air alone (pH 8.2, approximating a pCO₂ of 380 ppm) or with a controlled mixture of air/CO₂ (pH 7.8, approximating a pCO₂ of 780 ppm),” while “arm length, total body wet weight, and righting responses were measured weekly.” Then, after 97 days, which they describe as “a period of time sufficient for 80% arm regeneration,” they say that “protein, carbohydrate, lipid and ash levels were determined for body wall and pyloric caecal tissues of intact and regenerating arms of individuals held in both seawater pH treatments.”

In describing their findings, the four U.S. researchers report that “adults of the common soft bottom predatory sea star Luidia clathrata exposed to end-of-century conditions of ocean acidification (pH 7.8) are relatively unimpaired in their regenerative capacity,” which “encompasses not only their ability to re-grow their arms, but their ability to allocate materials and energy to regenerated somatic body components.” In addition, they say “there is no discernable pattern arising from exposure to a reduced seawater pH of 7.8 for 97 days on righting behavior,” which they say is “an integrative measure of stress.” Schram et al. conclude the report of their work by stating that “the demonstration of an organism’s ability to sustain normal functions under these conditions is as equally important to document as those that are negatively impacted,” since “this information will be critical to future assessments of prospective impacts of ocean acidification at the community level.”

In prefacing their work, Schlegel et al. (2012) write that “environmental factors directly affect populations by selecting resilient individuals,” noting that “selection at the gametic level, or during early life, has strong and immediate effects at the population level, carrying over into subsequent life stages,” such that “heritability of this resilience leads to cascading adaptive effects in subsequent generations.” And as an example of this process, they report that “in free-spawning marine organisms, sperm selection during fertilization plays a key role by determining the nature and diversity of genotypes in the subsequent generation (Levitan, 1996; 2008) and thus their resilience to environmental change.”

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2 http://www.co2science.org/articles/V15/N4/82.php
3 http://www.co2science.org/articles/V16/N30/C3.php
Against this backdrop, Schlegel et al. investigated “the effects of CO$_2$-induced ocean acidification on the early life history stages in the Australasian sea urchin *Heliocidaris erythrogramma*, focusing on intra-specific variation in responses, which can be highly variable for this species (Evans and Marshall, 2005).” More specifically, and “following the A1FI-scenario from the IPCC’s 4th assessment report,” they “compared the effects of present day conditions for southeast Australia with the end-of-century scenario (pCO$_2$=970 ppm; pH=0.3 unit reduction) and a high-CO$_2$ scenario (pCO$_2$=1600 ppm; pH=0.5 unit reduction),” after which the “observed effects on sperm swimming behavior were applied within an established fertilization kinetics modeling framework (Vogel et al., 1982; Styan et al., 2008) to predict fertilization outcomes of single urchin pairs at each pCO$_2$ level.” Last of all, these results “were then compared to observed results from fertilization experiments conducted in the laboratory.”

Results of the analysis indicated that “acidification significantly decreased the proportion of motile sperm but had no effect on sperm swimming speed,” and the four researchers went on to state that the subsequent fertilization experiments “showed strong inter-individual variation in responses to ocean acidification, ranging from a 44% decrease to a 14% increase in fertilization success.”

In commenting on their findings, Schlegel et al. opined that their results suggest that “some individuals will exhibit enhanced fertilization success in acidified oceans, supporting the concept of ‘winners’ and ‘losers’ of climate change at an individual level.” And they say that if these differences are heritable, it is likely that “ocean acidification will lead to selection against susceptible phenotypes as well as to rapid fixation of alleles that allow reproduction under more acidic conditions,” which phenomena “may ameliorate the biotic effects of climate change if taxa have sufficient extant genetic variation upon which selection can act.”

Real world data supporting phenotypic adaptation to seawater of lower pH was provided by Moulin et al. (2011)$^4$, who conducted a field experiment on the sea urchin *Paracentrotus lividus* in an attempt “to compare the effect of pH on the progeny of individuals collected from the same shore, i.e., same population, but from distinct tide pools: one where night pH was significantly reduced and the other where this decline was not so important.” In doing so, the four Belgian researchers report that the pH of coastal seawater at the site they studied (Aber, Crozon peninsula, southern Brittany, France) was 8.14; but they say that at the

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$^4$ http://www.co2science.org/articles/V14/N42/B1.php
end of the night low tides, tide pools 1 (subtidal) and 2 (intertidal) had pH values of, respectively, 7.8 and 7.4. Under these conditions, they detected “no significant difference in gonad maturity between individuals from the two tide pools,” and they report that “the offspring of sea urchins from the tide pool with higher pH decrease (tide pool 2) showed a better resistance to acidification at pH 7.4 than that of sea urchins from the tide pool with low pH decrease (tide pool 1) in terms of fertilization, viz. a reduction of over 30% [for tide pool 1] compared to about 20% for tide pool 2.” Commenting on their findings, Moulin et al. conclude that “sea urchins inhabiting stressful intertidal environments produce offspring that may better resist future ocean acidification.” And they add that the fact that “the fertilization rate of gametes whose progenitors came from the tide pool with higher pH decrease was significantly higher,” suggests “a possible acclimation or adaptation of gametes to pH stress.”

Also studying *Paracentrotus lividus* was Martin et al. (2011)5, who write that “ocean acidification is predicted to have significant effects on benthic calcifying invertebrates, in particular on their early developmental states,” and they note that “echinoderm larvae could be particularly vulnerable to decreased pH, with major consequences for adult populations.” Against this backdrop the authors explored the effect of a gradient of decreasing pH from 8.1 to 7.0 -- corresponding to atmospheric CO\(_2\) concentrations of ~400 ppm to ~6630 ppm -- on the larvae of the sea urchin *Paracentrotus lividus*, a common but economically and ecologically important species that is widely distributed throughout the Mediterranean Sea and the northeast Atlantic from Ireland to southern Morocco. This was accomplished using “multiple methods to identify the response of *P. lividus* to CO\(_2\)-driven ocean acidification at both physiological (fertilization, growth, survival and calcification) and molecular (expression of genes involved in calcification and development) levels.”

Results indicated that “*Paracentrotus lividus* appears to be extremely resistant to low pH, with no effect on fertilization success or larval survival.” They did, however, discover that “larval growth was slowed when exposed to low pH,” such that larvae of *P. lividus* “collected at pH 7.5 at 46 hours post-fertilization (real age) were smaller than in the control treatment [pH 8.1] and corresponded to a virtual age of 36 hours (a delay in development of 10 hours).” Continuing, they further indicate that “down to a pH of 7.25, the larvae at Day 3 have a normal morphology but are delayed in development,” such that the apparent decrease in calcification at that point in time is, as they put it, “simply an indirect consequence of the impact of low pH on developmental rate.” Or in other words, as they continue, “at a given developmental state (or size), larvae present the same calcium incorporation rate regardless of pH.” They also report that “genes involved in development and biomineralization were upregulated by factors of up to 26 at low pH,” which suggests “plasticity at the gene expression level” in *P. lividus* that “allows a normal, but delayed, development under low pH conditions.”

Introducing their study, Ericson et al. (2010)6 write that in polar latitudes “the effects of changing pCO\(_2\) and pH on gametes may be influenced by the carbonate chemistry of cold water, such as the already higher pCO\(_2\) and lower seawater pH,” and they say “it has also been predicted that ocean acidification effects on organisms may be more apparent and appear earliest in polar

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5 http://www.co2science.org/articles/V14/N18/B3.php
6 http://www.co2science.org/articles/V14/N21/B1.php
waters.” To explore this situation further, Ericson et al. “investigated the effects of present-day pH 8.0, predicted ocean surface pH for the years 2100 and 2300 (pH 7.7 and pH 7.3, respectively) and an extreme pH (pH 7.0) on fertilization and embryogenesis in the Antarctic nemertean worm Parborlasia corrugatus and sea urchin Sterechinus neumayeri.”

According to the four researchers, results indicated that “fertilization success was not affected by pH in P. corrugatus across a range of sperm concentrations,” and that “fertilization success in S. neumayeri declined significantly in pH 7.0 and 7.3 seawater, but only at low sperm concentration.” In addition, they say that “seawater pH had no effect on the rate of egg cleavage in S. neumayeri, or the proportion of abnormal embryos 1-day post-fertilization,” and that “P. corrugatus embryogenesis was also relatively robust to pH changes, with a significant effect detected only when the seawater pH was decreased to 7.0.” Given such findings, Ericson et al. conclude, “as in a number of other studies (see reviews by Byrne et al., 2010; Dupont et al., 2010), that gametes appeared relatively robust to pH change, especially to changes within the range predicted for the near future (i.e. a decrease of 0.3-0.5 pH units),” and they state that their initial findings “do not support a view that polar species are more affected by lowered pH compared with temperate and tropical counterparts (as has also been shown for the later developmental stages of S. neumayeri (Clark et al., 2009)).”

Yu et al. (2013) also studied Sterechinus neumayeri, as they too were concerned about how the early life stages of this sea urchin are impacted by the levels of atmospheric CO₂ enrichment being predicted to occur within the current century. Specifically, Yu et al. tested the effects of high CO₂/low pH on early development and larval growth by exposing them to environmental levels of CO₂ in McMurdo Sound (control: 410 ppm) and mildly elevated CO₂ levels, both near the level of the aragonite saturation horizon (510 ppm), and to under-saturating conditions (730 ppm). Under such conditions, the researchers report that over the course of development from egg to late four-arm pluteus, they found that “(1) early embryological development was normal with the exception of the hatching process, which was slightly delayed, (2) the onset of calcification as determined by the appearance of CaCO₃ spicule nuclei was on schedule, (3) the lengths of the spicule elements, and the elongation of the spicule nuclei into the larval skeleton, were significantly shorter in the highest CO₂ treatment four days after the initial appearance of the spicule nuclei, and (4) finally, without evidence of true developmental delay, larvae were smaller overall under high CO₂ treatments; and arm length, the most plastic morphological aspect of the echinopluteus, exhibited the greatest response to high CO₂/low pH/low carbonate conditions.” As a result of these finding Yu et al. concluded that “effects of elevated CO₂ representative of near future climate scenarios are proportionally minor on these early development stages.”

Working with the purple sea urchin (Strongylocentrotus purpuratus), Yu et al. (2011) raised larvae in seawater maintained at pCO₂ levels ranging from ambient to 1,000 and 1,450 ppm CO₂ (pH 7.7 and 7.5, respectively), while measuring, after three and six days development, “total larval length (from the spicule tip of the postoral arm to the spicule tip of the aboral point) along the spicules, to assess effects of low pH upwelling water on morphology.” Results indicated that

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7 http://www.co2science.org/articles/V16/N25/B2.php
8 http://www.co2science.org/articles/V14/N32/B1.php
“even at the highest pCO₂ treatments, larval development was normal in terms of timing and morphological appearance,” although at both day 3 and 6 larvae in the 1450-ppm CO₂ treatment were 7-13% smaller than control larvae. Yu et al. also state that “the observed developmental progression and survival of cultures was within the norm typically observed for this species at this temperature range.” In addition, they indicate that “a lack of developmental deformities at early stages for pCO₂ ~1000 ppm has been previously reported for this species (Todgham and Hofmann, 2009), and another local species, *Lytechinus pictus*, with a similar overlapping portion of its range in southern California (O’Donnell et al., 2010).” And they say “there are even reports that survival is increased in this species and its congener *S. droebachiensis* under some low pH conditions (Dupont and Thorndyke, 2008).” Thus, it would appear, as Yu et al. conclude, that “the effects of small magnitude in these urchin larvae are indicative of a potential resilience to near-future levels of ocean acidification.”

Also focusing on *Strongylocentrotus purpuratus*, Stumpp et al. (2011a)⁹ evaluated the impacts of elevated seawater pCO₂ (1264 ppm vs. 375 ppm) on the early development of, and the larval metabolic and feeding rates of, this model marine organism. This was done via a protocol where growth and development were assessed daily, for a period of three weeks, in terms of total body length, body rod length, postoral rod length and posterolateral rod length, as well as mortality and feeding and metabolic rates. Results of the analysis indicated that daily mortality rate (DMR) was significantly higher under control conditions (DMR = 2.7% per day) in comparison to that under high seawater pCO₂ (DMR = 2.2% per day).

It was also observed, in the elevated CO₂ treatment, that larval development was about 8% slower, such that it took slightly longer for equivalent development stages to be reached in the high CO₂ treatment.

As a result of the slower development of the larvae in the high CO₂ treatment, at any given time the individuals in this treatment were found to be smaller and less well developed than those in the control treatment; and if that was the only comparison to have been made in this study, the effects of elevated CO₂ might have been thought to have been negative. But if comparisons are made on the basis of development stage, as was also done in this study, it would have been found -- and was! -- that there were no long-term physical differences between the larvae living in the high and low CO₂ treatments.

But if comparisons are made on the basis of development stage, as was also done in this study, it would have been found -- and was! -- that there were no long-term physical differences between the larvae living in the high and low CO₂ treatments.

In light of these observations, it can be appreciated that in studies designed to reveal the effects of atmospheric CO₂ enrichment upon various species of marine life, treatment comparisons should be made at equivalent development stages of the organism being studied; since at such

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⁹ http://www.co2science.org/articles/V15/N15/B2.php
points along the life cycle of the purple sea urchin, there were no significant physical differences between individuals raised in the control and CO$_2$-enriched conditions. As Stumpp et al. thus declare at the conclusion of their enlightening study, “we suggest that body length is a useful scale of reference for studies in sea urchin larvae where a morphological delay in development occurs,” and that “using time post-fertilization as a reference may lead to misinterpretation of data,” i.e., to wrongfully assuming a negative result, when in reality there may be no deleterious effect of ocean acidification. This is essentially the same conclusion reached by Stumpp et al. (2011b) in a companion paper, where they say that “in studies in which a stressor induces an alteration in the speed of development, it is crucial to employ experimental designs with a high time resolution in order to correct for developmental artifacts,” which protocol “helps prevent misinterpretation of stressor effects on organism physiology.”

Noting that “little is known about the adaptive capacity of species to respond to an acidified ocean,” and, as a result, “predictions regarding future ecosystem responses remain incomplete,” Pespeni et al. (2013)$^{10}$ conducted a study that demonstrates that ocean acidification generates striking patterns of genome-wide selection in purple sea urchins (*Strongylocentrotus purpuratus*) cultured under different CO$_2$ levels of 400 and 900 ppm. Working with seven different populations collected along a 1,200-km mosaic of coastal upwelling-driven acidification of the California Current System, Pespeni et al. combined (1) sequencing across the transcriptome of the purple sea urchin, (2) growth measurements under experimental acidification, and (3) tests of frequency shifts in 19,493 polymorphisms during development, while detecting in the process “the widespread occurrence of genetic variation to tolerate ocean acidification.”

In describing their findings, the eleven researchers report that although larval development and morphology showed little response to elevated CO$_2$, they found “substantial allelic change in 40 functional classes of proteins involving hundreds of loci.” More particularly, they state that “pronounced genetic changes, including excess amino acid replacements, were detected in all populations and occurred in genes for biomineralization, lipid metabolism, and ion homeostasis - gene classes that build skeletons and interact in pH regulation,” while noting that “such genetic change represents a neglected and important impact of ocean acidification that may influence populations that show few outward signs of response to acidification.” In considering all of the above, the researchers conclude “our results demonstrate the capacity for rapid evolution in the face of ocean acidification and show that

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10 http://www.co2science.org/articles/V16/N37/B3.php
standing genetic variation could be a reservoir of resilience to climate change in this coastal upwelling ecosystem.”

Examining another species of urchin, Catarino et al. (2012) studied the development of larvae produced by adults of the Arbacia dufresnei urchin, which they collected from a sub-Antarctic population in the Straits of Magellan near Punta Arenas, Chile, when immersed in high (8.0), medium (7.7) and low (7.4) pH seawater. The five scientists state their analysis showed that “the proportion of abnormal larvae did not differ according to [pH] treatment,” with the result that although “lower pH induced a delay in development” -- which has also been noted by Dupont et al. (2010) -- it “did not increase abnormality.” They additionally indicate that “even at calcium carbonate saturation states <<1, skeleton deposition occurred,” and they further note in this regard that specimens of Heliocidaris erythrogramma also “seem not to be affected by a pH decrease (until 7.6),” citing Byrne et al. (2009a,b), while likewise noting that the Antarctic Sterechinus neumayeri is also thought to be “more robust to ocean acidification than tropical and temperate sub-tidal species,” citing Clark et al. (2009) and Ericson et al. (2010). The findings of Catarino et al., as well as those of the other researchers they cite, thus suggest that “polar and sub-polar sea urchin larvae can show a certain degree of resilience to acidification.” And they conclude that because of this fact, A. dufresnei has the potential to “migrate and further colonize southern regions.”

Writing as background for their study, Sunday et al. (2011) state that the presumed acidification of Earth’s oceans is predicted to impact marine biodiversity via “physiological effects impacting growth, survival, reproduction and immunology, leading to changes in species abundances and global distributions.” However, they note that “the degree to which these changes will play out critically depends on the evolutionary rate at which populations will respond to natural selection imposed by ocean acidification,” and they say that this phenomenon “remains largely unquantified,” citing the work of Stockwell et al. (2003) and Gienapp et al. (2008). Against this backdrop, working with a sea urchin species (Strongylocentrotus franciscanus) and a mussel species (Mytilus trossulus) in a full-factorial breeding study, Sunday et al. measured the potential for an evolutionary response to ocean acidification in the larval development rate of the two coastal invertebrates.

In discussing their findings, the four researchers report their experiment revealed that “the sea urchin species Strongylocentrotus franciscanus has vastly greater levels of phenotypic and genetic variation for larval size in future CO₂ conditions compared to the mussel species Mytilus trossulus,” and using these findings, they go on to demonstrate that “S. franciscanus may have faster evolutionary responses within 50 years of the onset of predicted year-2100 CO₂ conditions despite having lower population turnover rates.” Sunday et al. conclude their study by saying their comparisons suggest that “information on genetic variation, phenotypic variation, and key demographic parameters, may lend valuable insight into relative evolutionary potentials across a large number of species,” thereby also indicating that simplistic climate envelope models of species redistributions in a future CO₂-enriched and possibly warmer world are just not up to the task of providing a picture of future biological reality. And they solidify this view by noting that

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11 http://www.co2science.org/articles/V15/N23/B3.php
12 http://www.co2science.org/articles/V14/N46/B3.php
“a genetic basis for variation in CO₂ responses has been found in the three previous studies in which it has been sought (Langer et al., 2009; Parker et al., 2011; Pistevos et al., 2011), supporting the notion that genetic variation exists at some level for almost all quantitative characters (Roff, 1997).”

Introducing their work that was performed on yet another urchin species, Moulin et al. (2014) note it has been suggested that in numerous marine organisms several physiological processes may be directly or indirectly impacted by the induced acidosis and hypercapnia produced by continued atmospheric CO₂ enrichment; and they indicate that species with low metabolism and inefficient ion regulatory abilities have been suggested to be “more sensitive to a high seawater pCO₂,” citing Melzner et al. (2009). In light of these facts, Moulin et al. set forth to evaluate “the acid-base regulation of the coral reef sea urchin Echinometra mathaei and the impact of decreased pH on its growth and respiration activity,” which they did “in two identical artificial reef mesocosms during seven weeks,” when the experimental tanks were maintained at mean pH values of 8.05 (standard) and 7.7 (“acidified”), together with “field-like night and day variations.”

Key among their findings, the five Belgian researchers report that “E. mathaei can regulate the pH of its coelomic fluid in the considered range of pH.” As a result, Moulin et al. conclude that this ability allows “a sustainable growth” and ensures “an unaffected respiratory metabolism, at least at short term,” diminishing metabolism-based concerns for this marine species under elevated CO₂ conditions.

In an experiment designed to gain a better understanding of the effects of long-term exposure of adult Echinometra sp. EE sea urchins native to the Red Sea’s Gulf of Aqaba, Hazan et al. (2014) studied specimens they collected there within eleven 37.5-liter glass aquariums they maintained in equilibrium with air containing either 435 or 1,433 µatm of CO₂ -- corresponding respectively to seawater pH values of 8.1 and 7.7 -- for a period of eleven months, while they periodically examined them for somatic and gonadal growth and skeletal microstructure, during which time all urchins in the experiment completed full reproductive cycles typical of natural populations.

This work revealed that in the cases of (1) somatic and (2) gonadal growth, there were no significant differences between the sea urchins maintained in the two CO₂ treatments. They also state that there was “no detectable impact of increased pCO₂ on the [3] timing, [4] duration or [5] progression of the cycle.” And they add that “scanning electron microscopy imaging of urchin tests and spines revealed no signs of the usual observed effects of acidosis, such as [6] skeletal

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13 http://www.co2science.org/articles/V17/oct/a29.php
14 http://www.co2science.org/articles/V18/feb/a19.php
dissolution, [7] widened stereo pores or [8] non-smoothed structures.” Taken together, these several findings, in the words of the four researchers, “suggest high resistance of adult Echinometra sp. EE to near future ocean acidification conditions.”

Finally, concluding with another longer-term study of ocean acidification (OA) effects on sea urchins, Moulin et al. (2015)15 write that “due to their low metabolism and poor osmoregulation abilities, sea urchins have been considered as victims of OA,” but they note that past studies of the subject suggest that some adult sea urchins are able to maintain the pH of their coelomic fluid when faced with a decrease of seawater pH, citing the work of Dupont and Thorndyke (2012), Stumpp et al. (2012), Calosi et al. (2013), Collard et al. (2013, 2014), Moulin et al. (2014) and Uthicke et al. (2014). However, they write that “previous studies exposed sea urchins brutally to increased pCO₂ levels whereas gradual acclimatization will better mimic future OA.” And they also note that in all prior studies of post-metamorphic sea urchins: (1) the algae the urchins were fed were supplied to them ad libitum, and (2) the algae had not been grown under OA conditions.

In their study, therefore, the Belgian researchers placed specimens of the sea urchin Echinometra mathaei in “replicated mesocosms provided with an artificial reef consisting of hermatypic scleractinians and reef calcareous substrate with its diverse communities of algae as principal food,” after which the mesocosms experienced six months of gradual pH decrease until an OA pH level of 7.7 was reached. These conditions were then maintained for seven additional months, during which time a number of pertinent parameters were monitored, while at the conclusion of the experiment the bio-mechanical resistance of the sea urchins’ skeletons was assessed.

After evaluating the many measurements they made of E. mathaei and its activities over the course of their study, Moulin et al. (2015) concluded that the urchin appeared to be resilient to ocean acidification levels expected to occur by 2100 in terms of “acid-base regulation, growth, respiration rate and test mechanical properties,” all of which findings play a significant role in determining the sea urchin’s interactions with both algae and corals.

In summation, with the passage of time, more and more evidence is accumulating that suggests the impacts of ocean acidification on echinoderms may not be as bad as many initially thought. Indeed, for many echinoderm species, the impacts will likely be minimal, if not altogether positive.

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15 http://www.co2science.org/articles/V18/may/a23.php


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Cover photo of *Tripneustes ventricosus* (West Indian Sea Egg-top) and *Echinometra viridis* (Reef Urchin - bottom) by Nick Hobgood as posted to *Wikipedia* under *Creative Commons Attribution-ShareAlike 3.0 Unported* license.