Data on hatching frequency and success from an experiment on CO2 sensitivity of Northern sand lance (Ammodytes dubius) embryos conducted in 2020

Website: https://www.bco-dmo.org/dataset/867931
Data Type: Other Field Results, experimental
Version: 1
Version Date: 2022-01-12

Project
» Collaborative research: Understanding the effects of acidification and hypoxia within and across generations in a coastal marine fish (HYPOA)

<table>
<thead>
<tr>
<th>Contributors</th>
<th>Affiliation</th>
<th>Role</th>
</tr>
</thead>
<tbody>
<tr>
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<td>University of Connecticut (UConn)</td>
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<td>BCO-DMO Data Manager</td>
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</table>

Abstract
Source data of two years of experimentation on Northern sand lance (Ammodytes dubius) embryos at different temperature and pCO2 conditions. Founder adults were sampled at Stellwagen Bank National Marine Sanctuary (SBNMS) (42° 9' 58.26" N, 70° 18' 44.19" W). Two complementary experiments were conducted in late 2018 (E1) and 2020 (E2), each rearing newly fertilized sand lance embryos to hatch over the course of 32-65 days. This dataset includes information from the switch experiment (E2) in 2020.

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Coverage
Spatial Extent: Lat: 42.166183 Lon: -70.312275
Temporal Extent: 2020-11-27

Acquisition Description

Experimental setup: Two complementary experiments were conducted in late 2018 (E1) and 2020 (E2), each rearing newly fertilized sand lance embryos to hatch over the course of 32-65 days. Founder adults were sampled at Stellwagen Bank National Marine Sanctuary (SBNMS) (42° 9' 58.26" N, 70° 18' 44.19" W) at the peak of their narrow, local spawning window on November 15th (E1) or 27th (E2), using a 1.3 ×
0.7 m beam trawl (6 mm mesh) towed over ground at 3 knots for 15 min. On deck, all flowing-ripe males and females were strip-spawned together (at 10°C, E1: N\text{male/female} = 29/13; E2: N\text{male/female} = 50/46) and their progeny transported to the University of Connecticut's Rankin Seawater Lab. There, exposure experiments commenced within 8 hours post fertilization by placing a volumetrically measured random sample of 600 (E1) or 1,200 embryos (E2) into each replicate rearing container.

Experimental seawater was drawn from subsurface eastern Long Island Sound (~31 psu), filtered to 1 μm, and UV-sterilized before use. Oxygen levels were maintained at ~100% saturation, while the photoperiod was 11L:13D.

**Seawater chemistry:** Realized pCO₂ conditions and other seawater chemistry parameters (Table 1 of Baumann et al., MEPS (in review)) were estimated in CO2SYS (V2.1, Pierrot et al. 2006) based on samples taken every 10 days and measured for temperature, pHNIST, salinity (refractometer) and total alkalinity (AT, μmol kg⁻¹). Seawater samples were filtered to 10 μm, stored in 300 ml borosilicate bottles at 3°C, and within days measured for AT using endpoint titration (Mettler Toledo® G20 Potentiometric Titrator) with an accuracy of ±1% (Murray et al. 2019; verified and calibrated using Dr. Andrew Dickson's certified reference material for AT in seawater; Scripps Institution of Oceanography, Batch Nr. 162 & 164).

**Experimental designs:** During E1, we tested factorial combinations of two static temperatures and three target pCO₂ levels, thereby encompassing contemporary thermal conditions on Stellwagen Bank between late fall (10°C) and early winter (6°C), as well as current ambient (400 μatm, pH~8.12), predicted end-of-century (1,000 μatm, pH~7.76), and maximum open ocean pCO₂ benchmarks (2,000 μatm, pH~7.48; Caldeira & Wickett 2003, Salisbury & Jönsson 2018). At 10°C, three additional, pCO₂ levels below 1,000 μatm (570, 690, 890 μatm, Table 1) were included to better describe near future CO₂ sensitivities of sand lance embryos. The replication level for each of the 9 treatments was N = 5. Another 50 embryos per replicate were subsampled 90-190 ddpf and preserved in buffered (sodium tetraborate) 5% formaldehyde-in-freshwater solution. Those embryos sampled just before hatching began (170 ddpf, one random replicate per treatment) were later submitted for sectioning and staining (H&E stain; Horus Scientific, Worcester, MA), and later imaged for analyses of chorionic thickness (Nikon SMZ-1000 with Luminera® Infinity2-2 camera and ImagePro Premier v9.0, Media Cybernetics®).

During E2, we again tested target pCO₂ levels of 400, 1,000, and 2,000 μatm, first at an intermediate static temperature of 7°C and second at a dynamic temperature of 10°C decreasing to 5°C at a rate of 0.2°C d⁻¹ (105°C). The latter was chosen to approximate the seasonal decline in bottom temperatures experienced by sand lance embryos on Stellwagen Bank. The two treatments reached thermal equivalence at 32 dpf (224 ddpf) – just after hatching had started. To better describe sand lance upper CO₂-sensitivities (1,000 - 2,000 μatm), we added two intermediate pCO₂ levels at 7°C (~1,300; ~1,700 μatm) and one at 105°C (~1,300 μatm). The initial replication level for each of the 9 treatments was N = 6. However, to disentangle potential pCO₂ effects on embryonic development vs. effects on hatching itself, we switched three random replicates from each extreme pCO₂ treatment with the opposite pCO₂ treatment (i.e., 3× ~400 --> ~2,000 μatm and 3× ~2,000 --> ~400 μatm). The switch happened at 175 ddpf (25 dpf at 7°C; 22dpf at 105°C) just before hatching started.

**Response traits:** From 90 ddpf onwards, rearing containers were monitored daily until hatching commenced; then, the number of hatchlings per replicate was recorded daily until hatching ceased. All hatchlings were immediately preserved in buffered 5% formaldehyde/freshwater solution for later morphological measurements. At the conclusion of E1, unhatched remains were imaged at 4× magnification, allowing the later distinction between (a) early arrested embryos (no or only amorphous cell masses visible), (b) partially developed embryos (unpigmented eyes visible, body not fully wrapped around the egg), and (c) fully developed embryos (pigmented eyes, body clearly visible and more than 1× wrapped around; Fig.S2). In E2, we continued daily monitoring for 7 more days after hatching had ceased; then examined the remains microscopically for embryos still alive (i.e., with beating hearts). Absolute hatching numbers were transformed to daily relative frequencies via dividing by the initial number of embryos that was adjusted for subsampling (E1, N = 500 per replicate) or reduced fertilization success (E2, N = 873 per replicate, based on examining independent post-fertilization subsamples). Relative frequencies were then summed to yield cumulative hatching success (HS, %) for each replicate. For E1, we additionally calculated the proportions of (a) fully developed but unhatched embryos and (b) all other arrested embryos combined. The latter also included decayed stages that were no longer detectable at the
To characterize hatching phenology, we recorded the day of first hatch (dpf), day of peak hatch (dpf with the highest relative hatch frequency), and the total hatching period (d) for each replicate. Following Murray et al. (2019), a large number of hatchlings were imaged at 4× magnification (E1: $N_{\text{total}} = 3,923$; E2: $N_{\text{total}} = 2,659$) and then individually measured (ImagePro) for three morphological traits, i.e., standard length (SL, nearest 0.01 mm), yolk sac area (nearest 0.001 mm$^2$), and the size of the remaining oil globule inside the yolk sac (nearest 0.001 mm$^2$). The latter two traits are proxies for endogenous energy reserves after hatching, but they were strongly correlated ($N = 5,552$; $R = 0.62$, $p < 0.001$). Hence, we used PCA to extract the first principal component (explaining 73% (E1), 81% (E2) of variability) and then used the PC1 scores as the new variable, hereafter referred to as ‘Endogenous Energy Reserves’ (EER). Histological sections of fully developed, pre-hatch embryos from E1 were imaged at 20× magnification to measure the thickness of the chorion (ImagePro). Chorion thickness was measured at 10 randomly selected locations around the circumference of the sectioned embryo, with measurements averaged subsequently for each embryo. Unfortunately, fewer than expected embryos were sectioned well enough for quality measurements, ranging from 2-7 per treatment.

**Processing Description**

**BCO-DMO Processing:**
- changed dates to format YYYY-MM-DD;
- removed commas from data columns.

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**Related Publications**

Baumann, H., Jones, L.F., Murray, C.M., Siedlecki, S., and Cross, E.L. Why are sand lance embryos so sensitive to future oceanic CO2 conditions? Marine Ecology Progress Series (in review)

*Results*

*Methods*

*Methods*

*Methods*

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**Related Datasets**

IsRelatedTo


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**Parameters**
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<th>Parameter</th>
<th>Description</th>
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<td>Fertilization</td>
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<td>microatmospheres (uatm)</td>
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<td>Rel_HS</td>
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<td>Rel_HS_control</td>
<td>Cumulative mean hatching success across all control pCO2 replicates</td>
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Instruments
### Dataset-specific Instrument Name
- **beam trawl (6 mm mesh)**

### Generic Instrument Name
- **Beam Trawl**

### Generic Instrument Description
A beam trawl consists of a cone-shaped body ending in a bag or codend, which retains the catch. In these trawls the horizontal opening of the net is provided by a beam, made of wood or metal, which is up to 12 m long. The vertical opening is provided by two hoop-like trawl shoes mostly made from steel. No hydrodynamic forces are needed to keep a beam trawl open. The beam trawl is normally towed on outriggers, one trawl on each side. While fishing for flatfish the beam trawl is often equipped with tickler chains to disturb the fish from the seabed. For operations on very rough fishing grounds they can be equipped with chain matrices. Chain matrices are rigged between the beam and the groundrope and prevent boulders/stones from being caught by the trawl. Shrimp beam trawls are not so heavy and have smaller mesh sizes. A bobbin of groundrope with rubber bobbins keeps the shrimp beam trawl in contact with the bottom and gives flatfish the opportunity to escape. Close bottom contact is necessary for successful operation. To avoid bycatch of most juvenile fishes selectivity devices are assembled (sieve nets, sorting grids, escape holes). While targeting flatfish the beam trawls are towed up to seven knots, therefore the gear is very heavy; the largest gears weighs up to 10 ton. The towing speed for shrimp is between 2.5 and 3 knots. (from: [http://www.fao.org/fishery/geartype/305/en](http://www.fao.org/fishery/geartype/305/en))

### Dataset-specific Instrument Name
- **Water Temperature Sensor**

### Generic Instrument Name
- **Water Temperature Sensor**

### Generic Instrument Description
General term for an instrument that measures the temperature of the water with which it is in contact (thermometer).

### Dataset-specific Instrument Name
- **pH Sensor**

### Generic Instrument Name
- **pH Sensor**

### Generic Instrument Description
An instrument that measures the hydrogen ion activity in solutions. The overall concentration of hydrogen ions is inversely related to its pH. The pH scale ranges from 0 to 14 and indicates whether acidic (more H+) or basic (less H+).
A refractometer is a laboratory or field device for the measurement of an index of refraction (refractometry). The index of refraction is calculated from Snell's law and can be calculated from the composition of the material using the Gladstone-Dale relation. In optics the refractive index (or index of refraction) $n$ of a substance (optical medium) is a dimensionless number that describes how light, or any other radiation, propagates through that medium.

**Dataset-specific Instrument Name**
Mettler Toledo G20 Potentiometric Titrator

**Generic Instrument Name**
Automatic titrator

**Generic Instrument Description**
Instruments that incrementally add quantified aliquots of a reagent to a sample until the end-point of a chemical reaction is reached.

**Dataset-specific Instrument Name**
Nikon SMZ-1000 stereo microscope

**Generic Instrument Name**
Microscope - Optical

**Generic Instrument Description**
Instruments that generate enlarged images of samples using the phenomena of reflection and absorption of visible light. Includes conventional and inverted instruments. Also called a "light microscope".

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**Project Information**

**Collaborative research: Understanding the effects of acidification and hypoxia within and across generations in a coastal marine fish (HYPOA)**

**Coverage:** Eastern Long Island Sound, CT, USA

*Description from NSF award abstract:*
Coastal marine ecosystems provide a number of important services and resources for humans, and at the same time, coastal waters are subject to environmental stressors such as increases in ocean acidification and reductions in dissolved oxygen. The effects of these stressors on coastal marine organisms remain poorly understood because most research to date has examined the sensitivity of species to one factor, but not to more than one in combination. This project will determine how a model fish species, the Atlantic silverside, will respond to observed and predicted levels of dissolved carbon dioxide (CO2) and oxygen (O2). Shorter-term experiments will measure embryo and larval survival, growth, and metabolism, and determine whether parents experiencing stressful conditions produce more robust offspring. Longer-term experiments will study the consequences of ocean acidification over the entire life span by quantifying the
effects of high-CO2 conditions on the ratio of males to females, lifetime growth, and reproductive investment. These studies will provide a more comprehensive view of how multiple stressors may impact populations of Atlantic silversides and potentially other important forage fish species. This collaborative project will support and train three graduate students at the University of Connecticut and the Stony Brook University (NY), two institutions that attract students from minority groups. It will also provide a variety of opportunities for undergraduates to participate in research and the public to learn about the study, through summer research projects, incorporation in the "Women in Science and Engineering" program, and interactive displays of environmental data from monitoring buoys. The two early-career investigators are committed to increasing ocean literacy and awareness of NSF-funded research through public talks and presentations.

This project responds to the recognized need for multi-stressor assessments of species sensitivities to anthropogenic environmental change. It will combine environmental monitoring with advanced experimental approaches to characterize early and whole life consequences of acidification and hypoxia in the Atlantic silverside (Menidia menidia), a valued model species and important forage fish along most of the US east coast. Experiments will employ a newly constructed, computer-controlled fish rearing system to allow independent and combined manipulation of seawater pCO2 and dissolved oxygen (DO) content and the application of static and fluctuating pCO2 and DO levels that were chosen to represent contemporary and potential future scenarios in productive coastal habitats. First CO2, DO, and CO2 × DO dependent reaction norms will be quantified for fitness-relevant early life history (ELH) traits including pre- and post-hatch survival, time to hatch, post-hatch growth, by rearing offspring collected from wild adults from fertilization to 20 days post hatch (dph) using a full factorial design of 3 CO2 × 3 DO levels. Second, the effects of tidal and diel CO2 × DO fluctuations of different amplitudes on silverside ELH traits will be quantified. To address knowledge gaps regarding the CO2-sensitivity in this species, laboratory manipulations of adult spawner environments and reciprocal offspring exposure experiments will elucidate the role of transgenerational plasticity as a potential short-term mechanism to cope with changing environments. To better understand the mechanisms of fish early life CO2-sensitivity, the effects of temperature × CO2 on pre- and post-hatch metabolism will be robustly quantified. The final objective is to rear silversides from fertilization to maturity under different CO2 levels and assess potential CO2-effects on sex ratio and whole life growth and fecundity.

**Related references:**
