Supporting Material for

**Interaction between Pollution and Climate Change Augments Ecological Risk to a Coastal Ecosystem**

Yonglong Lu1,2,3 \*, Ruoshi Wang1,3, Yajuan Shi1, Chao Su1,2, Jingjing Yuan1,2, Andrew C. Johnson4, Alan Jenkins4, Robert C. Ferrier5, Deliang Chen6, Hanqin Tian7, Jerry Melillo8, Shuai Song1，Aaron M. Ellison9

1State Key Laboratory of Urban and Regional Ecology, Research Center for Eco-Environmental Sciences, Chinese Academy of Sciences, Beijing 100085, China

2University of Chinese Academy of Sciences, Beijing 100049, China

3Renmin University of China, 59 Zhongguancun Road, Beijing 100872, China

4Centre for Ecology and Hydrology, Maclean Building, Crowmarsh Gifford Wallingford, Oxon, OX 10 8BB, UK

5James Hutton Institute, Aberdeen AB15 8QH, Scotland, UK

6Department of Earth Sciences, University of Gothenburg, 405 30 Gothenburg, Sweden

7International Center for Climate and Global Change Research, and School of Forestry and Wildlife Sciences, Auburn University, Auburn, AL 36849, USA

8The Ecosystem Center, Marine Biological Laboratory, Woods Hole, MA 02543, USA

9Harvard University, Harvard Forest, 324 North Main Street, Massachusetts 01366, USA

\*Corresponding author: yllu@rcees.ac.cn

**S1 Supplementary figure of Bohai Sea region**



Figure S1 Yield of capture fisheries in Bohai Sea (1980-2014) (thousand tons)

**S2 Supplementary materials for pollution risk assessment**

**S2.1 DIN and SRP**

Table S1 Concentrations of dissolved inorganic nitrogen (DIN) in seawater of Bohai Sea

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Location | Year | Sample size | Concentration (μg/L) | References |
| Bohai Bay | 1980 | 49 | 299.00 | S4 |
| Central Sea | 1982-1983 | Nd | 28.00 | S5 |
| Central Sea | 1992-1993 | Nd | 27.52 | S2 |
| Central Sea | 1998-1999 | Nd | 80.00 | S5 |
| Bohai Sea | 1982 | 52 | 73.30 | S6 |
| Bohai Sea | 1992 | 52 | 147.25 | S6 |
| Bohai Sea | 1998 | 52 | 427.00 | S6 |
| Bohai Bay | 1995 | 20 | 998.00 | S7 |
| Bohai Bay | 2003 | 20 | 300.00 | S7 |
| Laizhou Bay | 1997.9 | 43 | 312.70 | S8 |
| Laizhou Bay | 1998.6 | 43 | 598.40 | S8 |
| Bohai Sea | 2002 | 120 | 193.44 | S9 |
| Bohai Sea | 2003 | Nd | 239.00 | S10 |
| Coastal sea | 2003 | Nd | 329.00 | S10 |
| Bohai Sea | 2004 | Nd | 401.00 | S11 |
| Coastal sea | 2004 | Nd | 430.00 | S11 |
| Bohai Sea | 2005 | Nd | 215.80 | S12 |
| Coastal sea | 2005 | Nd | 280.70 | S12 |
| Bohai Sea | 2006 | Nd | 270.00 | S13 |
| Bohai Sea | 2007 | Nd | 380.00 | S14 |
| Bohai Sea | 2009 | Nd | 224.40 | S15 |
| Bohai Bay | 2007 | 15 | 611.30 | S16 |
| Bohai Bay | 2008 | 15 | 823.58 | S16 |
| Bohai Bay | 2009 | 15 | 281.10 | S16 |
| Bohai Bay | 2010 | 15 | 543.40 | S16 |
| Bohai Bay | 2011 | 15 | 458.50 | S16 |
| Bohai Bay | 2012 | 15 | 731.10 | S16 |
| Liaodong Bay-Huludao | 2008 | 8 | 134.00 | S17 |
| Liaodong Bay-Jinzhou | 2008 | 4 | 278.00 | S17 |
| Liaodong Bay-Panjin | 2008 | 4 | 356.00 | S17 |
| Liaodong Bay-Yingkou | 2008 | 4 | 443.00 | S17 |
| Liaodong Bay-Dalian | 2008 | 7 | 174.00 | S17 |
| Liaodong Bay | 2014.5 | 20 | 510.80 | S18 |
| Liaodong Bay | 2014.8 | 20 | 287.65 | S18 |
| Liaodong Bay | 2014.10 | 20 | 425.90 | S18 |

Table S2 Concentrations of soluble reactive phosphorus (SRP) in seawater of Bohai Sea

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Location | Year | Sample size | Concentration (μg/L) | References |
| Bohai Bay | 1980 | 49 | 5.33 | S4 |
| Bohai Sea | 1982 | 52 | 92.15 | S6 |
| Bohai Sea | 1992 | 52 | 24.70 | S6 |
| Bohai Sea | 1998 | 52 | 30.40 | S6 |
| Bohai Bay | 2003 | 20 | 20.00 | S7 |
| Laizhou Bay | 1997 | 43 | 58.9 | S8 |
| Laizhou Bay | 1998 | 43 | 27.60 | S8 |
| Bohai Sea | 2003 | Nd | 12.20 | S10 |
| Coastal sea | 2003 | Nd | 15.20 | S10 |
| Bohai Sea | 2004 | Nd | 11.0 | S11 |
| Coastal sea | 2004 | Nd | 13.1 | S11 |
| Bohai Sea | 2005 | Nd | 19.30 | S12 |
| Coastal sea | 2005 | Nd | 27.20 | S12 |
| Bohai Sea | 2006 | Nd | 30.00 | S13 |
| Bohai Sea | 2007 | Nd | 20.00 | S14 |
| Bohai Sea | 2009 | Nd | 13.40 | S15 |
| Bohai Bay | 2007 | 15 | 24.30 | S16 |
| Bohai Bay | 2008 | 15 | 20.66 | S16 |
| Bohai Bay | 2009 | 15 | 14.43 | S16 |
| Bohai Bay | 2010 | 15 | 9.62 | S16 |
| Bohai Bay | 2011 | 15 | 13.30 | S16 |
| Bohai Bay | 2012 | 15 | 15.28 | S16 |
| Liaodong Bay-Huludao | 2008 | 8 | 11.00 | S17 |
| Liaodong Bay-Jinzhou | 2008 | 4 | 5.00 | S17 |
| Liaodong Bay-Panjin | 2008 | 4 | 32.00 | S17 |
| Liaodong Bay-Yingkou | 2008 | 4 | 13.00 | S17 |
| Liaodong Bay-Dalian | 2008 | 7 | 16.00 | S17 |
| Liaodong Bay | 2014.5 | 20 | 17.51 | S18 |
| Liaodong Bay | 2014.8 | 20 | 11.47 | S18 |
| Liaodong Bay | 2014.10 | 20 | 19.44 | S18 |

Table S3 Concentrations of DO in seawater of Bohai Sea

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Location | Year | Sample size | Concentration (μg/L) | References |
| Bohai sea | 2002 | 120 | 6510 | S9 |
| Bohai Sea | 2003 | nd | 6340 | S10 |
| Coastal sea | 2003 | nd | 6200 | S10 |
| Bohai Sea | 2004 | nd | 6529 | S11 |
| Coastal sea | 2004 | nd | 6508 | S11 |
| Bohai Sea | 2005 | nd | 6570 | S12 |
| Coastal sea | 2005 | nd | 6330 | S12 |
| Bohai Sea | 2006 | nd | 6500 | S13 |
| Bohai Sea | 2007 | nd | 6890 | S14 |
| Bohai Sea | 2009 | nd | 6630 | S15 |
| Bohai Bay | 2007 | 15 | 7330 | S16 |
| Bohai Bay | 2010 | 15 | 7720 | S16 |
| Bohai Bay | 2011 | 15 | 7400 | S16 |
| Bohai Bay | 2012 | 15 | 7450 | S16 |
| Liaodong Bay | 2014.5 | 20 | 9042 | S18 |
| Liaodong Bay | 2014.8 | 20 | 7256 | S18 |
| Liaodong Bay | 2014.10 | 20 | 8098 | S18 |

Table S4 Concentrations of Chl-a in seawater of Bohai Sea

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Location | Year | Sample size | Concentration (μg/L) | References |
| Bohai sea | 2002 | 120 | 1.82 | S9 |
| Bohai Sea | 2003 | Nd | 5.30 | S10 |
| Coastal sea | 2003 | Nd | 5.30 | S10 |
| Bohai Sea | 2004 | Nd | 3.04 | S11 |
| Coastal sea | 2004 | Nd | 3.91 | S11 |
| Bohai Sea | 2005 | Nd | 2.85 | S12 |
| Coastal sea | 2005 | Nd | 4.03 | S12 |
| Bohai Sea | 2006 | Nd | 2.82 | S13 |
| Bohai Sea | 2007 | Nd | 2.97 | S14 |
| Bohai Sea | 2009 | Nd | 2.57 | S15 |
| Bohai Bay | 2007 | 15 | 2.86 | S16 |
| Bohai Bay | 2008 | 15 | 5.76 | S16 |
| Bohai Bay | 2010 | 15 | 3.17 | S16 |
| Bohai Bay | 2011 | 15 | 2.84 | S16 |
| Bohai Bay | 2012 | 15 | 5.20 | S16 |

The data from Table S1 to S4 were applied to estimate the ecological risks of eutrophication in aquatic systems by using the trophic index (TRIX)(S1)

$TRIX=\frac{Log\left(Chl-a×\left[\%DO\right]×DIN×SRP+1.5\right)}{1.2}$

where Chl-a is the concentration of chlorophyll-a, %DO is the absolute value of the oxygen saturation deviation and is calculated as |100 - %DO|. The four following trophic levels were defined: high with TRIX < 4, good with 4 < TRIX < 5, fair with 5 < TRIX < 6, and poor with TRIX > 6. Here we used TRIX=4.5 to calculate risk of DIN and SRP by quotient method:

Risk=(TRIX-4.5)/4.5

Risk1980~2014=24.0%

**S2.2 Petroleum hydrocarbons**

Table S5 Concentrations of petroleum hydrocarbons (PHs) in seawater of Bohai Sea

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Location | Year | Sample size | Concentration (μg/L) | References |
| Bohai Bay | 1996 | 16 | 140.00 | S19 |
| Bohai Bay | 1997 | 16 | 139.00 | S19 |
| Bohai Bay | 1998 | 16 | 78.50 | S19 |
| Bohai Bay | 1999 | 16 | 128.00 | S19 |
| Bohai Bay | 2000 | 16 | 72.10 | S19 |
| Bohai Bay | 2001 | 16 | 35.80 | S19 |
| Bohai Bay | 2002 | 16 | 173.00 | S19 |
| Bohai Bay | 2003 | 16 | 95.90 | S19 |
| Bohai Bay | 2004 | 16 | 51.80 | S19 |
| Bohai Bay | 2005 | 16 | 48.90 | S19 |
| Bohai Bay | 2002 | 7 | 26.80 | S20 |
| Liaodong Bay | 2002 | 16 | 23.50 | S20 |
| Laizhou Bay | 2002 | 11 | 42.00 | S20 |
| Central Bohai | 2002 | 23 | 20.20 | S20 |
| Bohai Channel | 2002 | 5 | 25.70 | S20 |
| Bohai Sea | 2003 | Nd | 42.70 | S10 |
| Coastal sea | 2003 | Nd | 54.70 | S10 |
| Bohai Sea | 2004 | Nd | 104.90 | S11 |
| Coastal sea | 2004 | Nd | 140.30 | S11 |
| Bohai Sea | 2005 | Nd | 58.00 | S12 |
| Coastal sea | 2005 | Nd | 75.00 | S12 |
| Bohai Sea | 2006 | Nd | 50.00 | S13 |
| Bohai Sea | 2007 | Nd | 80.00 | S14 |
| Bohai Sea | 2009 | Nd | 33.50 | S15 |
| Bohai Bay | 2007 | 15 | 39.50 | S16 |
| Bohai Bay | 2008 | 15 | 30.40 | S16 |
| Bohai Bay | 2009 | 15 | 13.87 | S16 |
| Bohai Bay | 2010 | 15 | 31.30 | S16 |
| Bohai Bay | 2011 | 15 | 55.00 | S16 |
| Bohai Bay | 2012 | 15 | 35.00 | S16 |
| Bohai Bay | Spring 2010 | 4 | 10.50 | S21 |
| Bohai Bay | Autumn 2010 | 4 | 23.93 | S21 |
| Liaodong Bay | 2014.5 | 20 | 10.97 | S18 |
| Liaodong Bay | 2014.8 | 20 | 18.51 | S18 |
| Liaodong Bay | 2014.10 | 20 | 20.21 | S18 |

Table S6 Toxicity data of PHs

|  |  |  |  |
| --- | --- | --- | --- |
|  | Species Scientific Name | Species Group | EC50/LC50 (ug/l) |
| 1 | Allorchestes compressa | Amphipod | 10.00 |
| 2 | Eualus sp. | Crustaceans | 349.85 |
| 3 | Evasteriastroschelii | Invertebrates | 716.04 |
| 4 | Mysis oculata | Crustaceans | 1048.71 |
| 5 | Mysis oculata | Crustaceans | 1289.93 |
| 6 | Daphnia magna | Crustaceans; Standard Test Species | 2244.08 |
| 7 | Artemia sp. | Crustaceans | 4671.60 |
| 8 | Daphnia magna | Crustaceans | 4670.17 |
| 9 | Calanus hyperboreus | Crustaceans | 73000.00 |
| 10 | Palaemonetes sp. | Crustaceans | 4400558.68 |
| 11 | Skeletonema costatum | Algae | 13641727.31 |



Figure S2 Species Sensitivity Distribution(SSD) of PHs toxicity

Risks of PHs were calculated with probabilistic ecological risk assessment (RMPERA) method based on toxicity data of indigenous species.

RiskPHs=100%

**S2.3 Pb**

Table S7 Concentrations of Pb in seawater of Bohai Sea

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Location | Year | Sample size | Concentration (μg/L) | References |
| Bohai Bay | 1996-2005 | 22 | 4.43 | S22 |
| Liaodong Bay | 2001-2004 summer | 16 | 4.91 | S23 |
| Bohai Sea | 2002 | 52 | 3.29 | S24 |
| Bohai Sea | 2003 | 52 | 1.16 | S24 |
| Bohai Sea | 2003 | 42 | 1.10 | S25 |
| Bohai Bay | 2003 | 20 | 7.10 | S26 |
| Bohai Sea | 2003 | Nd | 1.48 | S10 |
| Coastal sea | 2003 | Nd | 1.77 | S10 |
| Bohai Bay | 2004 | 17 | 8.38 | S27 |
| Bohai Sea | 2004 | Nd | 1.95 | S11 |
| Coastal sea | 2004 | Nd | 1.87 | S11 |
| Bohai Sea | 2006-2007 | Nd | 2.43 | S28 |
| Bohai Bay | 2007 | 15 | 1.68 | S16 |
| Bohai Bay | 2008 | 15 | 0.70 | S16 |
| Bohai Bay | 2009 | 15 | 0.42 | S16 |
| Bohai Bay | 2010 | 15 | 0.42 | S16 |
| Bohai Bay | 2011 | 15 | 5.60 | S16 |
| Bohai Bay | 2012 | 15 | 1.68 | S16 |
| Liaodong Bay-Huludao | 2008 | 8 | 2.00 | S17 |
| Liaodong Bay-Jinzhou | 2008 | 4 | 6.00 | S17 |
| Liaodong Bay-Panjin | 2008 | 4 | 0.10 | S17 |
| Liaodong Bay-Yingkou | 2008 | 4 | 2.60 | S17 |
| Liaodong Bay-Dalian | 2008 | 7 | 1.20 | S17 |
| Northern Bohai | 2008 | Nd | 2.62 | S29 |
| Northern Liaodong Bay | 2009 | 20 | 3.43 | S30 |
| Laizhou bay | 2010 | Nd | 0.88 | S31 |
| Coastal Bohai Bay | 2011 | 18 | 3.13 | S32 |

Table S8 Toxicity data of Pb

|  |  |  |  |
| --- | --- | --- | --- |
| Rank | Species Scientific Name | Species Group | EC50/LC50 (ug/l) |
| 1 | Heterotrich Ciliate | Invertebrates | 12.85 |
| 2 | Chaetoceros sp. | Algae, Moss, Fungi | 105.00 |
| 3 | Ulva pertusa | Algae, Moss, Fungi | 489.00 |
| 4 | Nannochloropsisgaditana | Algae, Moss, Fungi | 740.00 |
| 5 | Rhodomonassalina | Algae, Moss, Fungi | 900.00 |
| 6 | Isochrysisgalbana | Algae, Moss, Fungi | 1340.00 |
| 7 | Tetraselmischuii | Algae, Moss, Fungi | 2640.00 |
| 8 | Brachionusplicatilis | Invertebrates; Standard Test Species | 4000.00 |
| 9 | Phaeodactylumtricornutum | Algae, Moss, Fungi | 5000.00 |
| 10 | Skeletonemacostatum | Algae, Moss, Fungi; Standard Test Species | 7940.00 |



Figure S3 Species Sensitivity Distribution(SSD) of Pb toxicity

Risks of PHs was calculated with probabilistic ecological risk assessment (RMPERA) method based on toxicity data of indigenous species.

RISKPb=1.02%

**S2.4 Concentrations of other pollutants and over standard rate**

Table S9 Concentrations of Hg in seawater of Bohai Sea

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Location | Year | Sample size | Concentration (μg/L) | References |
| Bohai Bay | 1980-1981 | 8 | 0.039 | S33 |
| Bohai Bay | 1996-2005 | 22 | 0.050 | S22 |
| Bohai Sea | 2002 | 52 | 0.070 | S24 |
| Bohai Sea | 2003 | 52 | 0.270 | S24 |
| Bohai Sea | 2003 | 42 | 0.030 | S25 |
| Bohai Bay | 2003 | 20 | 0.040 | S26 |
| Bohai Sea | 2003 | Nd | 0.043 | S10 |
| Coastal sea | 2003 | Nd | 0.047 | S10 |
| Bohai Bay | 2004 | 17 | 0.080 | S27 |
| NothernBohai Sea | 2008 | 17 | 1.000 | S34 |
| Estuary of Huanghe | 2009 | Nd | 0.380 | S35 |
| Bohai Bay | 2010 | 15 | 0.087 | S16 |
| Bohai Bay | 2011 | 15 | 0.053 | S16 |
| Bohai Bay | 2012 | 15 | 0.108 | S16 |
| Laizhou bay | 2010 | Nd | 0.056 | S31 |
| Coastal Bohai Bay | 2011 | 18 | 0.037 | S32 |

Table S10 Concentration of Cd in seawater of Bohai Sea

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Location | Year | Sample size | Concentration (μg/L) | References |
| Jinzhou Bay | 1992-1993 | 22 | 1.13 | S36 |
| Bohai Bay,surface water | 1996-2005 | 22 | 0.2 | S22 |
| Liaodong Bay | 2001-2004 summer | 16 | 1.04 | S23 |
| Bohai Sea | 2002 | 52 | 0.47 | S24 |
| Bohai Sea | 2003 | 52 | 0.35 | S24 |
| Bohai Sea | 2003 | 42 | 0.31 | S25 |
| Bohai Bay | 2003 | 20 | 0.12 | S26 |
| Bohai Sea | 2003 | Nd | 0.56 | S10 |
| Coastal sea | 2003 | Nd | 0.69 | S10 |
| Bohai Bay | 2004 | 17 | 0.38 | S27 |
| Bohai Sea | 2006-2007 | Nd | 0.16 | S28 |
| Bohai Bay | 2007 | 15 | 0.22 | S16 |
| Bohai Bay | 2009 | 15 | 0.10 | S16 |
| Bohai Bay | 2010 | 15 | 0.08 | S16 |
| Bohai Bay | 2011 | 15 | 0.44 | S16 |
| Bohai Bay | 2012 | 15 | 0.16 | S16 |
| Bohai Bay | 2008 | 20 | 0.15 | S37 |
| Northern Liaodong Bay | 2009 | 20 | 0.60 | S30 |
| Laizhou bay | 2010 | Nd | 0.28 | S31 |
| Coastal Bohai Bay | 2011 | 18 | 0.36 | S32 |

Table S11 Over standard rate of pollution stressors

|  |  |  |  |
| --- | --- | --- | --- |
| Stressors  | Sea water quality standard (μg/L) \* | Median concentration (μg/L) | Over standard rate |
| DIN | 200 | 310 | 0.55 |
| SRP | 15 | 20.3 | 0.35 |
| PHs | 50 | 31.5 | 0.00 |
| Pb | 1 | 1.68 | 0.68 |
| Hg | 0.05 | 0.055 | 0.10 |
| Cd | 1 | 0.33 | 0.00 |

\*China sea water quality standard (GB 3097-1997), standards for first class seawater (fisheries area) (S38)

**S3 Supplementary materials for climate change risk assessment**

**S3.1 Ocean warming**



Figure S4 Effect of temperature on plankton biomass (S39)



Figure S5 Annual SST anomaly from the 1900 to 2010 mean in Bohai (S40)

1945 and 2006 (blue dotted line) were two sudden change years. SST increased 0.015 ℃/a on average from 1960 to 2010. SST of Bohai in the summer of 1980 was 23.9 ℃ (S41), and it was 24.4℃ in 2014.

SST rise risk= (effect 2014-effect 1980)/effect 1980=6.4%

**S3.2 Ocean acidification**



Figure S6 Effect of CO2 concentration on plankton (S42)

Table. S12 Effect of CO2 concentration on plankton

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
|  | Intercept | Slope(a) | F-value | P |
| Calcification | 6.226 | -0.830 | 15.00 | <0.001 |
| Fertility | 3.141 | -0.314 | 67.59 | <0.0001 |
| Survival | 2.864 | -0.220 | 29.34 | <0.0001 |
| All | -7.383 | 1.058 | 12.81 | <0.001 |

We choose survival as the risk assessment endpoint in this study.

Survival Rate(SR)=-0.220\*ln (CO2) +2.864



Figure S7 Monthly average CO2 concentration from 1990 to 2014 in China (S43)

CO2 (1980) = 339.1 ppm；CO2 (2014) = 404.4 ppm

Ocean acidification risk = (SR 2014-SR 1980)/SR 1980 = 2.3%

**S3.3 UV-B**

The UV-B spectrum (280nm~315nm) of UV light that is most harmful to organisms.

Table S13 UV-B effects on planktons (S46-S48)

|  |  |  |
| --- | --- | --- |
| Species | Endpoint | UV-B (kJ/m2) |
| Schmacheriainopinus male | 24h-LD50 | 5.77 |
| Schmacheriainopinuscopepodite | 24h-LD50 | 3.573 |
| Harpacticus sp. Female | EC50 | 2.51 |
| E.pacifica male | 24h-LD50 | 2.653 |
| E.pacifica female | 24h-LD50 | 5.158 |
| E.pacificacopepodite | 24h-LD50 | 2.347 |



Fig S8 SSD of UV-B effects on planktons (HC5=1.8 kJ/m2)

Table S14 UV-B radiation of 5 observation stations around Bohai area (KJ/m2/d)

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| Station | 2006-2012 UV(S49) | 1991 UV\* | 2012-UV\* | 1991 UV-B\*\* | 2012 UV-B\*\* | 1991 UV-B in sea\*\*\* | 2012 UV- B in sea\*\*\* |
| JZW | 523.0 | 510.4 | 526.5 | 13.8 | 14.2 | 3.6 | 3.7 |
| NM | 614.0 | 601.4 | 617.5 | 16.2 | 16.7 | 4.2 | 4.3 |
| NMG | 703.0 | 690.4 | 706.5 | 18.6 | 19.1 | 4.8 | 5.0 |
| SYG | 515.0 | 502.4 | 518.5 | 13.6 | 14.0 | 3.5 | 3.6 |
| YC | 480.0 | 467.4 | 483.5 | 12.6 | 13.1 | 3.3 | 3.4 |

(\*The linear trends of long-term annual mean daily whole UV radiation were 0.7 kJ/m2/d per year during 1991-2012 (S50). \*\*UV-B makes up about 2.7% of the total UV radiation energy reaching earth surface(S51); \*\*\*For UV of 310nm spectrum in ocean, radiation energy deceases 14% while water depth increases 1 m(S52). The average depth of Bohai is 18m. Here we use the median value, in the depth of 9 m, oceanic UV-B decreases to 26% on surface earth.)

UV-B rise risk=risk (2012)-risk (1991) =1.7%

Table S15 Risk results of climate change stressors

|  |  |
| --- | --- |
| Stressors | Risk |
| Ocean warming (SST, °C) | 6.4% |
| Ocean acidification (CO2, ppm) | 2.3% |
| Sea level rise (mm) | 10.7% |
| UV-B(KJ/m2) | 1.7% |

Table S16 Change rate of climate change stressors

|  |  |  |  |
| --- | --- | --- | --- |
| Stressors  | 1980 | 2014 | Change rate over 35 years |
| SST (°C) | 23.9 | 24.4 | 0.021 |
| CO2 (ppm) | 339.1 | 404.4 | 0.19 |
| Sea level (mm) | 17916.00(S45) | 18018.00(S45) | 0.006 |
| UV-B (KJ/m2) | 3.9 (1991) | 4.0(2012) | 0.026 |

**S4 Supplementary tables of relative vulnerability weights and impact weights**

Table S17 Ranking systems for each vulnerability measure used to assess how threats affect ecosystems (Adapted from S53)

|  |  |  |  |
| --- | --- | --- | --- |
| Vulnerability measure | Category | Rank | Notes |
| Scale (km2) | no impact | 0 |  |
| 0-10 | 1 |  |
| 10-100 | 2 |  |
| 100-1000 | 3 |  |
| >1000 | 4 |  |
| Frequency | never occurs | 0 |  |
| rare | 1 |  |
| occasional | 2 | frequent but irregular |
| annual or regular | 3 | frequent and seasonal |
| persistent | 4 |  |
| Functional and structure impact | no impact | 0 |  |
| species | 1 |  |
| population | 2 | single trophic level affected |
| community | 3 | multiple trophic level affected |
| ecosystem | 4 |  |
| Resistance | no impact | 0 |  |
| high | 1 |  |
| medium | 2 |  |
| low | 3 |  |
| no resistance | 4 |  |
| Recovery time (years) | no impact | 0 |  |
| <1 | 1 |  |
| 1-10 | 2 |  |
| 10-100 | 3 |  |
| >100 | 4 |  |

All score data were rescaled between 0 and 1.

Table S18 Relative vulnerability weights

|  |  |  |
| --- | --- | --- |
| Stressors | Coastal ecosystems | Marine ecosystems |
| Estuarine zone | Salt marsh | Rocky intertidal | Intertidal mud (reed marsh) | Beach | Seagrass bed | Rocky reef | Sea water | Deep benthic |
| Climate change | Ocean warming | 0.21 | 0.18 | 0.30 | 0.19 | 0.50 | 0.26 | 0.26 | 0.25 | 0.28 |
| Ocean acidification | 0.16 | 0.17 | 0.10 | 0.14 | 0.00 | 0.18 | 0.15 | 0.14 | 0.19 |
| UV-B rise | 0.13 | 0.14 | 0.10 | 0.18 | 0.00 | 0.06 | 0.09 | 0.11 | 0.03 |
| Pollution | DIN&SRP | 0.20 | 0.19 | 0.16 | 0.20 | 0.13 | 0.31 | 0.15 | 0.22 | 0.15 |
| PHs | 0.09 | 0.12 | 0.13 | 0.10 | 0.17 | 0.07 | 0.15 | 0.12 | 0.13 |
| Heavy metals | 0.21 | 0.20 | 0.21 | 0.20 | 0.20 | 0.12 | 0.20 | 0.16 | 0.22 |

Table S19 Impact weights of climate change on pollution stressors

|  |  |  |  |
| --- | --- | --- | --- |
|  | Ocean warming | Ocean acidification | UV-B |
| DIN&SRP | 0.54  | 0.30  | 0.16  |
| PHs | 0.16  | 0.54  | 0.30  |
| Heavy metals | 0.25  | 0.50  | 0.25  |

Table S20 Impact weights of pollution on climate change stressors

|  |  |  |  |
| --- | --- | --- | --- |
|   | DIN&SRP | PHs | Heavy metals |
| Ocean warming | 0.5 | 0.25 | 0.25 |
| Ocean acidification | 0.14 | 0.33 | 0.53 |
| UV-B | 0.16 | 0.54 | 0.3 |

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