Table of contents

Introduction	1
1) Global change and its consequences in the marine realm	1
1. The increase in atmospheric CO_2 : cause of many changes	1
2. Ocean acidification	
2.1. Carbonate chemistry of seawater	2 2 7
2.2. Time series : evidence for ongoing changes	7
2.3. Environments showing natural low pH	8
The intertidal	9
Upwelling zones	10
CO ₂ vents	11
l	12
2.4. Predictions for the near-future	12
2) Impact on organisms	14
	14
1.1. Acid-base regulation	14
1.2. Hypercapnia and/or acidosis	16
2. Impact on organisms : general aspects	18
3) Echinoderms facing changes in acidity	19
	19
2. Ecological importance	20
3. The coelomic fluid of echinoderms	21
4. Impact of ocean acidification on the « spiny skin » members	23
4.1. General considerations	24
4.2. Impact on early-life stages (embryo to larva)	24
4.3. Impact on post-metamorphic echinoderms (juvenile to adult)	25
Aims of the study 2	27
Chapters 2	28
1	28
	28
	28 29
	29 31
	35
	40
	43
	43

Chapter 2 : Euechinoidea and Cidaroidea respond differently to	44
ocean acidification	
Abstract	44
1. Introduction	45
2. Materials and Methods	46
3. Results	52
4. Discussion	59
5. Conclusion	62
Acknowledgements	62
Chapter 3: Could Antarctic sea urchins be more resilient to near-	63
future ocean acidification than expected?	
Abstract	63
1. Introduction	64
2. Materials and Methods	66
3. Results	67
4. Discussion	71
Acknowledgements	74
from intertidal pools, CO_2 vents and a long-term acidification experiment	
Abstract	
1. Introduction	76
2. Materials and Methods	76 77
	77
3. Results	77 79
 Results Discussion 	77 79 86
	77 79
4. Discussion Acknowledgements	77 79 86 89
4. Discussion	77 79 86 89 94
 4. Discussion Acknowledgements Chapter 5: Acid-base physiology response to ocean acidification 	77 79 86 89 94
 4. Discussion Acknowledgements Chapter 5: Acid-base physiology response to ocean acidification of two ecologically and economically important holothuroids from 	77 79 86 89 94
 4. Discussion Acknowledgements Chapter 5: Acid-base physiology response to ocean acidification of two ecologically and economically important holothuroids from contrasting habitats, Holothuria scabra and Holothuria parva 	77 79 86 89 94 95
 4. Discussion Acknowledgements Chapter 5: Acid-base physiology response to ocean acidification of two ecologically and economically important holothuroids from contrasting habitats, Holothuria scabra and Holothuria parva Abstract 	77 79 86 89 94 95
 4. Discussion Acknowledgements Chapter 5: Acid-base physiology response to ocean acidification of two ecologically and economically important holothuroids from contrasting habitats, Holothuria scabra and Holothuria parva Abstract Introduction Materials and Methods Results 	77 79 86 89 94 95 95 95
 4. Discussion Acknowledgements Chapter 5: Acid-base physiology response to ocean acidification of two ecologically and economically important holothuroids from contrasting habitats, Holothuria scabra and Holothuria parva Abstract Introduction Materials and Methods Results Discussion 	77 79 86 89 94 95 95 95 96 97
 4. Discussion Acknowledgements Chapter 5: Acid-base physiology response to ocean acidification of two ecologically and economically important holothuroids from contrasting habitats, Holothuria scabra and Holothuria parva Abstract Introduction Materials and Methods Results Discussion Conclusions 	77 79 86 89 94 95 95 95 95 96 97 103
 4. Discussion Acknowledgements Chapter 5: Acid-base physiology response to ocean acidification of two ecologically and economically important holothuroids from contrasting habitats, Holothuria scabra and Holothuria parva Abstract Introduction Materials and Methods Results Discussion 	

Discussion	110
1) Acid-base regulation in echinoderms	111
1. Acid-base status of echinoderms	111
2. Acid-base regulation facing ocean acidification	112
3. Consequences of OA on echinoderms	115
4. How do other factors impact the response to OA?	123
4.1. Food	123
4.2. Temperature	124
2) Impact of the natural environment	125
1. Stable high pH vs. fluctuating pH	125
2. Stable low pH environments	126
3) What could happen by 2100?	127
1. Will OA have an impact on echinoderms?	127
2. Potential for adaptation or evolution?	132
3. Impacts for the environment	133
4) Conclusions and perspectives	134

Appendixes

Appendix 1. pH of the internal fluid of invertebrate species. **Appendix 2**. Impact of ocean acidification (and secondary stressors) on echinoderm species: complete data. 137

Appendix 3. Collard M et al. (2013) Effects of CO₂-induced ocean acidification on physiological and mechanical properties of the starfish *Asterias rubens. Journal of Experimental Marine Biology and Ecology*, **446**, 355-362.

Appendix 4. Statistical analysis data for all variables tested for the three sea urchin species. Chapter 2.

Appendix 5. *In situ* measurements of seawater parameters at collection sites and carbonate system parameters calculated from CO2SYS using pH_T , A_T , *in situ* salinity and temperature. Chapter 3

Appendix 6. Measured parameters of the coelomic fluid (CF) and seawater in situ (SW). Chapter 3.

Appendix 7. Statistical analysis data for all variables tested for both species of sea cucumbers. Chapter 5.