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ICED Programme (Integrating Climate and Ecosystem Dynamics in the Southern Ocean)

Report Authors: Integrating Climate and Ecosystem Dynamics in the Southern Ocean programme (ICED).

Summary of activities from 2016-18 and other important issues - ICED is a regional programme of Future Earth and the Scientific Committee on Ocean Research's (SCOR) Integrated Marine Biosphere Research programme (IMBeR), and is a Co-sponsored Group of SCAR. ICED is undertaking integrated circumpolar analyses to improve our understanding of change and the implications for Southern Ocean ecosystems and their management. By providing a focus for linking Southern Ocean research communities across disciplines a diverse range of science is underway. Recent highlights include an expanding body of research on key species and food webs, on the links between biogeochemistry and ecology, and on the effects of change. ICED's current major focus is to build on this to comprehensively assess (and where possible quantify) the impacts of change on Southern Ocean ecosystems. This will be achieved through the analysis and integration of available data together with the development of models, scenarios and projections. These activities and outputs will provide valuable information for ecosystem-based management and policy. A summary of key ICED scientific highlights during the ten years since its inception was presented at the ICED-sponsored conference on Marine Ecosystem Assessment of the Southern Ocean (MEASO) held in April 2018.

Recommendations – ICED wishes to continue to work with SCAR to complement and add value to our work, learn from shared experience, and collectively address common goals. We would like SCAR to particularly note the mutually beneficial opportunities for strengthening interactions and collaborations with ICED. This includes (i) our ongoing work with the Commission for the Conservation of Marine Living Resources (CCAMLR) and the Committee for Environmental Protection (CEP), see below Plans and Linkages, and (ii) our work on models, scenarios and projections of change in Southern Ocean ecosystems (including our recent Projections Workshop (April 2018) and the ICED-sponsored MEASO Conference (April 2018)). As such we recommend that where possible, SCAR encourages, endorses and participates in relevant ongoing and upcoming ICED activities (see below).

Summary Budget 2017 to 2020 – no budget request

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Progress and Plans

Major Activities

1. **Understanding and quantifying the state and variability of marine ecosystems -** ICED has continued to develop whole ecosystem level understanding of the structure and functioning of Southern Ocean of ecosystems, their variability and response to change across a range of spatial and temporal scales. We have focused detailed work on key species from phytoplankton to whales (Arthur et al, Kaufman et al 2017, Meyer et al 2017), and the structure of food webs (e.g. Saunders et al 2017). We have also examined physical, chemical and biological interactions (e.g. Belcher et al 2017, Beekmans 2017) and the effects of past (Tarling et al 2018) and recent variability and change, such as ocean acidification (e.g. Bellerby et al. in prep, Manno et al 2017, Peck et al 2017, Trimbourne et al 2017). Much of this work was brought together during the ICED-sponsored conference on Marine Ecosystem Assessment of the Southern Ocean (MEASO) held in April 2018.
2. **Improving scenarios, predictions and projections of future ocean-human systems at multiple scales -** We have continued our model development work in support of creating a suite of models of physical dynamics (ocean circulation and climate), biogeochemical cycles, and biological dynamics (life histories, population dynamics, food web structure) within a hierarchical framework of models of different spatial, temporal and trophic resolution. The ultimate aim of these activities will be to advance end-to-end ecosystem modelling approaches that integrate physical, chemical and biological processes. Recent work includes. Dinniman et al 2017, Freer et al 2017, Kruger et al 2018, Silber et al 2017, Murphy et al. 2017, Meyer et al, 2018, Klein et al. 2018.

   We have used our understanding of the drivers and impacts of climate change in the Southern Ocean to further our work on developing scenarios of key drivers and projections of ecological change. For example, ICED scientists have published a recent ICED community paper Cavanagh et al. (2017). To follow on from this work, an ICED Projections workshop was held in April 2018, in collaboration with the Commission for the Conservation of Antarctic Marine Living Resources (CCAMLR), to further the scenarios and projections work.
3. **Improving and achieving sustainable ocean governance -** ICED has worked with stakeholders to ensure our science is incorporated into adaptation, mitigation and sustainable management procedures by improving two way communications and understanding between science, policy and society. ICED is continuing its work with the Antarctic Treaty Commission SCAR, and with the Committee for Environmental Protection (CEP) and CCAMLR. ICED is also continuing to work with other relevant international environmental treaties and organisations, conservation groups, and international committees. Examples include: an ICED Information Paper for the 2017 ATCM (ICED 2017) outlining the role that ICED can continue to play in providing information on climate change impacts on ecosystems to the Antarctic Treaty; an ICED paper was submitted to the WG-EMM meeting in July 2017 held in Buenos Aires, Argentina (Murphy et al. 2017a) detailing the ICED Projections Workshop that was held in April 2018 bringing together scientists involved in ICED and CCAMLR, as well as future joint

research between ICED, CCAMLR and SCAR; several publications were submitted by ICED scientists to CCAMLR in support of fisheries management and development of future MPA's (see Appendix); a range of ICED science and position papers have been submitted to the International Whaling Commission (IWC) and the Agreement on the Conservation of Albatrosses and Petrels (ACAP); ICED scientists have also led a science-policy initiative in Cambridge, UK and a science-policy fora as part of the MEASO2018 Conference; ICED scientists are also involved in high level IPCC work.

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Outcomes

Sub-group	Activity/Outcome/Benefit/Achievement
ICED	ICED Community Paper (Cavanagh et al. 2017)
ICED	ICED Projections Workshop, Hobart, April 2018
ICED	10 years of ICED at the MEASO Conference, Hobart, April 2018

Notable Papers

1. Cavanagh RD, Murphy EJ, Bracegirdle TJ, Turner J, Knowland CA, Corney SP, Smith WO, Waluda CM, Johnston NM, Bellerby RGJ, Constable AJ, Costa DP, Hofmann EE, Jackson JA, Staniland IJ, Wolf-Gladrow D, Xavier JC. (2017). A Synergistic Approach for Evaluating Climate Model Output for Ecological Applications doi:10.3389/fmars.2017.00308.'
   This work was developed as an ICED Community paper and followed a workshop on Southern Ocean change. The multidisciplinary study stresses the need for an integrated approach to understand the effects of climate change on Antarctic marine ecosystems.
2. Murphy, E.J., Thorpe, S.E., Tarling, G.A., Watkins, J.L., Fielding, S., and Underwood, P. (2017b) Restricted regions of enhanced growth of Antarctic krill in the circumpolar Southern Ocean. Scientific Reports 7, 6963.
   The work is part of a large project aimed at developing a series of models of the population dynamics and life-cycle of Antarctic krill. The results and model analyses presented in this study contribute to core ICED activities aimed at developing projections of the impacts of change in Southern Ocean ecosystems and will be input to CCAMLR to inform decision making.
3. Meyer, Bettina, Freier, Ulrich, Grimm, Volker, Groeneveld, Jürgen, Hunt, Brian P. V., Kerwath, Sven, King, Rob, Klaas, Christine, Pakhomov, Evgeny, Meiners, Klaus M., Melbourne-Thomas, Jessica, Murphy, Eugene J., Thorpe, Sally E., Stammerjohn, Sharon, Wolf-Gladrow, Dieter, Auerswald, Lutz, Götz, Albrecht, Halbach, Laura, Jarman, Simon, Kawaguchi, So, Krumpen, Thomas, Nehrke, Gernot, Ricker, Robert, Sumner, Michael, Teschke, Mathias, Trebilco, Rowan, Yilmaz, Noyan I. (2017). The winter pack-ice zone provides a sheltered but food-poor habitat for larval Antarctic krill. Nature Ecology & Evolution 10.1038/s41559-017-0368-3
   This study is an important development in our understanding of the overwintering biology of Antarctic krill, which is crucial for developing projections of the impacts

of future change, and will be incorporated into further ICED and CCAMLR work in this area.

Future Actions

Science publications

- **Future directions in Southern Ocean ecosystems research (running title). (in prep.). Johnston et al. and the ICED SSC.** This ICED community manuscript will include motivations for the future development of the ICED Programme in coordinating and directing circumpolar integrated ecosystem science, its achievements over the past decade, and future scientific directions in Southern Ocean ecosystems and climate research;
- **Southern Ocean Acidification (in prep.). Bellerby, Constable, Hoppema, Hoppema, Kurihara, Lenton, Lo Monaco, Lovenduski, Meredith, Murphy, Shadwick, Suckling Trimborn. SCAR Reports.** SCAR formed an Action Group (AG) on Ocean Acidification to write this report. The AG and publication has been led by Richard Bellerby (ICED scientist and SSC member), and includes contributions from Constable (ICED SSC scientist member) Murphy (ICED scientist and SSC chair);
- A set of ICED papers from the recent ICED Projections Workshop and MEASO conference (see above).

Activities

- A range of ICED-led workshops and meetings to synthesise our research to date, forming a comprehensive view of status and changes in Southern Ocean ecosystems. Planned activities include:
    - ICED will have a strong presence at Polar2018, Davos, Switzerland, June 2018;
    - ICED input to CCAMLR's Working Group on Ecosystem Monitoring and Management, June 2018;
    - ICED plans to convene a session/workshop on Southern Ocean scenarios and projections at the IMBeR OSC in 2019.
- ICED scientists are involved in planning a repeat of the CCAMLR2000 krill synoptic survey led by scientists from Norway.
- New National Science Foundation Funded project Foraging Ecology and Physiology of the Leopard Seal (Hydrurga leptonyx). This three-year project will focus on the Antarctic Peninsula. 1st field effort April-May 2018. Livingston Island. PI Dan Costa, CoPIs, Steve Trumble, Shane Kanatous and Dan Crocker. This project will be aimed at better understanding the ability of the leopard seal, an apex predator in the Antarctic ecosystem, to cope with a changing environment.

Budget – no funds requested

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Linkages

Direct support - We will receive funds from IMBeR to conduct our next SSC meeting (2019).

Major collaborations

Within SCAR

1. **AnT-ERA: ICED** has links with SCAR's AnT-ERA programme, including most recently via contributions to the paper (Gutt et al. 2018) from the SCAR Cross-Program Workshop (on Interactions between Biological and Environmental Processes in the Antarctic, Institut de Ciències del Mar, 16-18 September 2015, Barcelona).
2. **SCAR's Action Group on Ocean Acidification:** ICED scientist and SSC member, Richard Bellerby, leads SCAR's Action Group on Ocean Acidification. This group are due to complete an Ocean Acidification report for SCAR, for imminent publication.
3. **SCAR-SCOR Southern Ocean Observing System (SOOS):** ICED SSC Member Andrew Constable is Co-Vice Chair (Biology) and leading the development of ecosystem Essential Ocean Variables. Constable is facilitating collaboration between ICED and SOOS in delivering co-ordinated field activities in different sectors of the Southern Ocean, co-ordinated delivery of data and field planning products, and assessments of change. He is also facilitating joint activities to deliver a benchmarking of Southern Ocean ecosystems in 2022. Dan Costa, Walker Smith and Eileen Hofmann of the ICED SSC are also involved in strengthening SOOS-ICED collaborations. ICED scientists will contribute to other SOOS regional working group meetings to be held during the course of 2018, as well as to a number of SOOS Capability Working Groups, including on benchmarking Southern Ocean ecosystems, ecosystem Essential Ocean Variables and sensing Antarctic predators from satellites.

Outside SCAR

1. **CCAMLR**: ICED is continuing close work with CCAMLR to ensure that ICED science is relevant to CCAMLR and that scientific results are translated appropriately into messages that resonate with policy makers (see above for details). ICED is also working with SCAR to encourage closer links between ICED, SCAR and SC-CAMLR (see previous annual report).
2. **CEP**: ICED scientists continue to engage with CEP, particularly regarding their climate change programme planning (see above for details).
3. **IMBeR and Future Earth**: ICED is a regional programme of IMBeR and as such connects upwards to Future Earth. Through these links ICED is continuing to raise the international profile of Southern Ocean science and ensure that our activities reflect international as well as regional priorities.
4. **EuroMarine**: ICED scientists are involved in the EuroMarine Network (see www.euromarinenetwork.eu), ensuring links between ICED and the shared vision of this European network whilst building on the legacy of EUR-OCEANS in developing the ICED network and science strategy.

5. **IPCC**: ICED scientists are involved in the Polar Regions Chapter for the IPCC Special Report on the Ocean and Cryosphere in a Changing Climate (lead author), and the Changing Ocean, Marine Ecosystems, and Dependent Communities Chapter (contributing authors).
6. **International Whaling Commission (IWC)**: ICED scientists are involved in key IWC work.

Outreach and Capacity Building

ICED has continued to progress with education and outreach activities, highlights include:

- Encouraging girls to pursue STEM careers (ICED Scientist Nadine Johnston);
- ICED contribution to the Portuguese National Workshop on Polar Education, March 2018;
- ICED contributions to APECS including presentations (at SCAR Biology, Leuven, 2017) and a panel discussion (MEASO, April 2018).

Appendix - ICED Publication list

(N.B. Many of these involve collaborations with SCAR scientists and scientists from other relevant programmes.)

1. Reports and Books

- Bellerby, R, Andrew Constable, Mario Hoppema, Haruko Kurihara, Andrew Lenton, Claire Lo Monaco, Nikki Lovenduski, Michael Meredith, Eugene Murphy, Elizabeth Shadwick, Coleen C. Suckling, Scarlett Trimborn. Southern Ocean Acidification report (In Prep).
- Constable, A.J., Melbourne-Thomas, J., Trebilco, R., Press, A.J., Haward, M. (2017) ACE CRC Position Analysis: Managing change in Southern Ocean ecosystems. Antarctic Climate and Ecosystems Cooperative Research Centre, Hobart, Australia. 39 pp.

2. Management and Policy related reports and papers to CCAMLR, IWC, ACAP etc.

- ICED (2017). Report on the activities of the Integrating Climate and Ecosystem Dynamics in the Southern Ocean (ICED) programme. ATCM XL 2017
- Murphy, Cavanagh, Johnston on behalf of the ICED SSC. 2017a. Integrating Climate and Ecosystem Dynamics in the Southern Ocean (ICED) program: developing ICED and CCAMLR joint activities. CCAMLR WG-EMM-17/36. CCAMLR Working Group on Ecosystem Monitoring and Management 2017.
- Other papers to CCAMLR Working Group on Ecosystem Monitoring and Management 2017 can be found here: https://www.ccamlr.org/en/wg-emm-17

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3. Scientific publications

- Ancel, André; Cristofari, Robin; Trathan, Phil N.; Gilbert, Caroline; Fretwell, Peter T.; Beaulieu, Michaël. 2017. Looking for new emperor penguin colonies? Filling the gaps. Global Ecology and Conservation, 9. 171-179.10.1016/j.gecco.2017.01.003 http://dx.doi.org/10.1016/j.gecco.2017.01.003
- Arthur, Benjamin; Hindell, Mark; Bester, Marthan; Nico De Bruyn, P.J.; Trathan, Phil; Goebel, Michael; Lea, Mary-Anne. 2017 Winter habitat predictions of a key Southern Ocean predator, the Antarctic fur seal (Arctocephalus gazella). Deep Sea Research Part II: Topical Studies in Oceanography, 140. 171-181. https://doi.org/10.1016/j.dsr2.2016.10.009
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- Belcher, Anna; Tarling, G.A.; Manno, C.; Atkinson, A.; Ward, P.; Skaret, G.; Fielding, S.; Henson, S.A.; Sanders, R. 2017. The potential role of Antarctic krill faecal pellets in efficient carbon export at the marginal ice zone of the South Orkney Islands in spring. Polar Biology, 40 (10). 2001-2013. https://doi.org/10.1007/s00300-017-2118-z
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- Cherel, Yves; Xavier, Jose C.; de Grissac, Sophie; Trouvé, Colette; Weimerskirch, Henri. 2017. Feeding ecology, isotopic niche, and ingestion of fishery-related items of the wandering albatross Diomedea exulans at Kerguelen and Crozet Islands. Marine Ecology Progress Series, 565. 197-215. 10.3354/meps11994 <http://dx.doi.org/10.3354/meps11994>
- Dinniman, M.S., J.M. Klinck, E.E. Hofmann, and W.O. Smith, Jr. 2018. Effects of projected changes in wind, atmospheric temperature and freshwater inflow on the Ross Sea. J. Climate 31: 1619-1635.
- Freer, Jennifer J.; Partridge, Julian C.; Tarling, Geraint A.; Collins, Martin A.; Genner, Martin J.. 2018 Predicting ecological responses in a changing ocean: the effects of future climate uncertainty. Marine Biology, 165 (1), 7. 18, pp. https://doi.org/10.1007/s00227-017-3239-1.
- Gardner, J., Manno, C., Bakker, D.C.E. et al. Mar Biol (2018) 165: 8. https://doi.org/10.1007/s00227-017-3261-3

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- Gregory, Susan; Collins, Martin A.; Belchier, Mark. 2017 Demersal fish communities of the shelf and slope of South Georgia and Shag Rocks (Southern Ocean). Polar Biology, 40 (1). 107-121. https://doi.org/10.1007/s00300-016-1929-7.
- Gutt J, Isla E, Bertler AN, Bodeker GE, Bracegirdle TJ, Cavanagh RD, Comiso JC,Convey P, Cummings V, De Conto R, De Master D, di Prisco G, d'Ovidio F, Griffiths HJ, Khan AL, López-Martínez J, Murray AE, Nielsen UN, Ott S, Post A, Ropert-Coudert Y, Saucède T, Scherer R, Schiaparelli S, Schloss IR, Smith CR, Stefels J, Stevens C, StrugnellJM, Trimborn S, Verde C, Verleyen E, Wall DH, Wilson NG, Xavier JC (2018) Cross-disciplinarity in the advance of Antarctic ecosystem research. Marine Genomics 37: 1-17 doi https://doi.org/10.1016/j.margen.2017.09.006
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- Hughes, Kevin A.; Grant, Susie M. 2017 The spatial distribution of Antarctica's protected areas: a product of pragmatism, geopolitics, or conservation need? Environmental Science & Policy, 72. 41-51. https://doi.org/10.1016/j.envsci.2017.02.009
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