Building 19, Chowder Bay
Road Mosman, NSW 2088
Ph:
Fax:
ABN:

Committee Secretary
Senate Standing Committees on Environment and Communications
PO Box 6100
Parliament House
Canberra ACT 2600

Re: Submission from the Sydney Institute of Marine Science to the Environment and Communications References Committee inquiry into the impacts of climate change on marine fisheries and biodiversity

Please find attached a submission to the Environment and Communications References Committee for their inquiry into the impacts of climate change on marine fisheries and biodiversity. This submission has been prepared by the Scientific Advisory Committee of the Sydney Institute of Marine Science (SIMS). SIMS is a marine science research institute founded by four major universities in the Sydney region (Macquarie University, the University of New South Wales, the University of Sydney, and the University of Technology Sydney). The Institute conducts multidisciplinary marine research across five core research themes; urbanisation, biodiversity, climate change, ocean resources, and marine management. SIMS is also the operator of the NSW node of the Australian Government's Integrated Marine Observing System – IMOS. The work of the Institute is conducted by marine scientists from all four of the founding universities and partner organizations including the NSW Office of Environment and Heritage, the Australian Museum and the NSW Department of Primary Industries. This provides SIMS with an extremely broad scope of professional expertise that is particularly pertinent to the Committee's inquiry into the impacts of climate change on marine fisheries and biodiversity.

In summary, the following submission was prepared by SIMS scientists who are internationally recognized experts in this area and have particular expertise in the marine science of climate change from an Australian perspective. Our submission focuses on areas for which we have a particularly high level of scientific expertise and knowledge. It is specifically designed to provide scientific evidence pertinent to the terms of reference for the Committee's inquiry. **The main conclusions of this submission are that: (i) climate change has already altered Australia's marine waters, (ii) these changes are already affecting marine biodiversity, and, (iii) the impacts of climate change on marine fisheries and biodiversity are likely to increase in the future.**

Yours sincerely,

Professor David A. Raftos,

Chair, Scientific Advisory Committee,

Email:

Submission prepared by the Sydney Institute of Marine Science for the Environment and Communications References Committee's inquiry into the impacts of climate change on marine fisheries and biodiversity

This submission provides scientific evidence pertinent to the Committee's terms of reference for their inquiry to assess "the current and future impacts of climate change on marine fisheries and biodiversity, including":

(a) **Recent and projected changes in ocean temperatures, currents and chemistry associated with climate change** – The is already evidence worldwide that climate change is warming the oceans, altering ocean currents and changing ocean chemistry (particularly through the process of ocean acidification). In the Australian context, it seems that the east coast of Australia is already one of the most heavily affected marine environments in the world resulting from an increase in the poleward penetration of the East Australian Current. In the past 60 years the temperature and salinity of our coast has effectively shifted 350 km south (Ridgway 2007), such that the region is warming at a rate of 2-3 times the global average. Southward transport within eddies is increasing (Cetina Heredia et al. 2014) and is expected to increase further in the future, at the detriment of eastward transport (to NZ) (Oliver et al. 2015).

(b) Recent and projected changes in fish stocks, marine biodiversity and marine ecosystems associated with climate change – Ocean warming has already affected global fisheries in the past four decades, leading to a 'tropicalisation' of catch. In other words, there has been an increase in the proportion of species with affinity for warm water (Cheung et al. 2013). The most widely documented impact of climate change on marine organisms is a poleward shift in their distributions, with species responding to warming ten times faster than on land at an average of 72 km per decade at the leading range edges (Poloczanska et al. 2013). Among marine species, phytoplankton distributions are moving fastest (470 km/ decade), followed by bony fish (278 km/ decade; Poloczanska et al. 2013), both at the leading range edges. Climate projections estimate that ocean isotherms will continue to shift poleward at a rate seven times faster in the 21st Century than the 20th Century (Sen Gupta et al. 2015), suggesting that these changes in distribution will become faster in the next few decades.

Examples of currently observable changes in Australia's marine fisheries and biodiversity are:

1. Declines and/or range-contraction of kelps and other habitat-forming cool-water seaweeds in both eastern (Johnson et al. 2011, Vergés et al. In press) and western Australia (Smale and Wernberg 2013, Wernberg et al. 2016). These seaweeds are foundation species that support entire ecological communities including some of Australia's most valuable fisheries (e.g. abalone and rock lobster), and are valued at over AU$10 billion per year (Bennett et al. 2016). The decline or disappearance of these foundation species is causing a profound shift in the associated ecological communities, which are mostly being replaced by turf algae and more tropical species (Bennett et al. 2015, Wernberg et al. 2016, Vergés et al. In press).

2. Range expansion of warm-water fishes and sea urchins from mainland Australia to Tasmania (Ling 2008, Ling et al. 2009, Last et al. 2011). Significantly, a recent study showed that marine

communities in no-take sanctuary zones are more stable and more resistant to colonisation by warm-water invading species than communities in fished reefs (Bates et al. 2014).

3. Increases in populations of tropical fish in temperate NSW reefs from Sydney Harbour to Narooma on the southern NSW coast (Booth et al., 2007), with ocean warming increasingly allowing tropical fishes to survive and overwinter in temperate waters (Figueira and Booth 2010).

4. It is also likely that changes in the structure of the East Australian Current will impact commercially significant fish stocks. The East Australian Current is distinguished from other ocean boundary currents by the frequency of eddy formation. It is really a current of eddies (Suthers et al. 2011). These eddies are forecast to increase in formation in the future, increasing the mixing of surface and deep layers and increasing plankton production (Matear et al. 2013). Recent observations suggest that eddies (swirls or vortexes) of the East Australian Current provide significant offshore habitats for larval fish compared to those on the continental shelf (Mullaney & Suthers (2013). Therefore stronger currents, greater mixing and eddy formation may increase the production of pelagic fish, albeit in more southern latitudes.

5. Climate change projections of coastal circulation under an A1B emissions scenario (in the 2060s) show that the increase in EAC eddies, and the increase in poleward penetration could result in an ~ 300k southward shift in the location of peak lobster larval settlement along the east coast of Australia. That is, a poleward shift in the lobster fishery by 300km. This will have significant impacts on the people working in the industry and for the management of the eastern rock lobster fishery (Cetina Heredia et al 2015).

(c) **Recent and projected changes in marine pests and diseases associated with climate change** – Ascribing the appearance or abundance of novel marine pests and diseases to climate change parameters is less straight forward than trends in biodiversity or fish stocks. However, there are obvious reasons to suspect that climate change will alter the dynamic between infectious microbes and the host organisms that they infect. It is now clear that outbreaks of infectious diseases are often linked to environmental stress. For instance, there is some evidence that susceptibility to QX disease, which limits productivity in Australia's Sydney rock oyster industry, may be increased after oysters become stressed, in some cases due to decreased water salinity after rainfall (Butt et al., 2006; Peters and Raftos, 2003). Hence, altered rainfall patterns associated with climate change may alter the prevalence of this disease. There is also preliminary evidence that outbreaks of Pacific Oyster Mortality Syndrome, a viral disease that currently threatens the viability of Pacific oyster farming in some areas of Australia, might occur after water temperature reaches a particular threshold.

(d) **The impact of these changes on commercial fishing and aquaculture, including associated business activity and employment** – Changes in ocean temperature, acidity and currents will have a broad range of effects on commercial fishing and aquaculture, many of which are interactive and so hard to predict. However, examples of these potential effects are relatively common. For instance, it is known that ocean acidification has substantial detrimental effects on fertilisation and development in oysters, to the extent that oysters may be unable to reproduce above certain threshold levels of acidification (Parker et al., 2009, 2010). Some work has shown that the genetic potential for adaptation in aquaculture species may be able to mitigate these effects (Gonçalves et al 2016; Parker et al., 2011). However, there is also emerging evidence that exploiting this capacity for genetic adaptation in selective breeding programs to produce climate change tolerant oysters may have negative effects on other traits.

e. The impact of these changes on recreational fishing – Climate change will have an impact on recreational fishing by changing the distribution, abundance, and seasonality of target species (Gannon et al. 2014; Payne et al. 2016). Changes to the distribution and abundance of fish will result in altered species composition and abundance of recreational catches. Highly mobile target species, such as pelagic fish (tuna, billfish, sharks), will alter the timing of their annual migrations and recreational fishers will need to adapt to these temporal and spatial changes in species distributions. Recreational fisheries have been identified as being particularly vulnerable to climate change as they have less capacity to adapt to altered target species and distributions (Ruckelshaus et al. 2013). Dynamic ocean management will be required to monitor and help recreational fisheries adapt to a changing ocean. For example, ocean forecasting tools are being used to predict the seasonal migration of dolphinfish to inform anglers of fish distribution and to improve the deployment of Fish Aggregation Devices (Brodie et al. in review).

(h) **The adequacy of biosecurity measures and monitoring systems given current and projected climate change impacts** – Australia already has strong biosecurity and monitoring systems designed to prevent the introduction of harmful marine pests. However, these systems are not infallible, as demonstrated by the recent appearance in Australia (likely from overseas) of the virus that causes Pacific Oyster Mortality Syndrome.

Scientific literature cited:

Bates, A. E., N. S. Barrett, R. D. Stuart-Smith, N. J. Holbrook, P. A. Thompson, and G. J. Edgar. 2014. Resilience and signatures of tropicalization in protected reef fish communities. Nature Climate Change **4**:62-67.

Bennett, S., T. Wernberg, S. D. Connell, A. J. Hobday, C. R. Johnson, and E. S. Poloczanska. 2016. The 'Great Southern Reef': social, ecological and economic value of Australia's neglected kelp forests. Marine and Freshwater Research **67**:47-56.

Bennett, S., Wernberg, T., Harvey, E.S., Santana-Garco, J. and Saunders, B.J. 2015. Tropical herbivores provide resilience to a climate-mediated phase shift on temperate reefs. Ecology Letters **18**:714-723.

Booth, D. J., Figueira, W. F., Gregson, M. A., Brown, L. and Beretta, G. 2007. Occurrence of tropical fishes in temperate southeastern Australia: role of the East Australian Current. Estuarine Coastal and Shelf Science. **72**:102–114.

Brodie, S., Hobday, A.H., Smith, J.A., Hartog, J., Spillman, C., Taylor, M.D., Gray, C.A. and Suthers, I.M. (in review). Seasonal forecasting of dolphinfish distribution in eastern Australia to aid recreational fishers and managers. Deep Sea Research Part II.

Butt, D., Shaddick, K. and Raftos, D.A. 2006. The effect of low salinity on phenoloxidase activity in Sydney Rock oysters. Aquaculture. **251**:159– 166.

Cetina Heredia, P. Roughan, M., Van Sebille, E. and Coleman, M.A. 2014. Long-term trends in the East Australian Current separation latitude and eddy driven transport. Journal of Geophysical Research Oceans, **119**: 4351–4366

Cetina-Heredia, P., Roughan M., van Sebille E., Feng M. and Coleman M. A. 2015. Strengthened currents override the effect of warming on lobster larval dispersal & survival. Global Change Biology **21**:4377-86.

Cheung, W. W., Watson, L.R and Pauly, D. 2013. Signature of ocean warming in global fisheries catch. Nature **497**:365-368.

Figueira, W. F. and D. J. Booth. 2010. Increasing ocean temperatures allow tropical fishes to survive overwinter in temperate waters. Global Change Biology **16**:506-516.

Gannon, R., Taylor, M.D., Suthers, I.M., Gray, C.A., van der Meulen, D.E., Smith, J.A and Payne, N.L. 2014. Thermal limitation of performance and biogeography in a free-ranging ectotherm: insights from accelerometry. Journal of Experimental Biology **217**: 3033-3037.

Gonçalves, P., Anderson, K., Thompson, E., Melwani, A., Parker, L., Ross, P. and Raftos, D. 2016. Rapid transcriptional acclimation following transgenerational exposure of oysters to ocean acidification. Molecular Ecology **25**: 4836-4849.

Johnson, C. R., Banks, S.C., Barrett, N.S., Cazassus, F., Dunstan, P.K., Edgar, G.J., Frusher, S.D., Gardner, C., Haddon, M., Helidoniotis, F., Hill, K.L., Holbrook, N.J., Hosie, G.W., Last, P.R., Ling, S.D., Melbourne-Thomas, J., Miller, K., Pecl, G.T., Richardson, A.J., Ridgway, K.R., Rintoul, S.R., Ritz, D.A., Ross, D.J., Sanderson, J.C., Shepherd, S.A., Slotvvinski, A., Swadling, K.M. and Taw, N. 2011. Climate change cascades: Shifts in oceanography, species' ranges and subtidal marine community dynamics in eastern Tasmania. Journal of Experimental Marine Biology and Ecology **400**:17-32.

Last, P. R., White, W.T, Gledhill, D.C, Hobday, A.J., Brown, R., Edgar, G.J. and Pecl, G. 2011. Long- term shifts in abundance and distribution of a temperate fish fauna: a response to climate change and fishing practices. Global Ecology and Biogeography **20**:58-72.

Ling, S. D. 2008. Range expansion of a habitat-modifying species leads to loss of taxonomic diversity: a new and impoverished reef state. Oecologia **156**:883-894.

Ling, S. D., Johnson, C.R, Frusher, S.D., and Ridgway, K.R. 2009. Overfishing reduces resilience of kelp beds to climate-driven catastrophic phase shift. Proceedings of the National Academy of Sciences of the United States of America **106**:22341-22345.

Matear, R.J., Chamberlain, M.A., Sun, C., and Feng M. 2013. Climate change projection of the Tasman Sea from an Eddy-resolving Ocean Model. Journal of Geophysical Research: Oceans **118**: 2961-2976.

Mullaney, T. and Suthers, I.M. 2013. Entrainment and retention of the coastal larval fish assemblage by a short-lived, submesoscale, frontal eddy of the East Australian Current. Limnology & Oceanography **58**: 1546–1556.

Oliver, E.C.J, O'Kane, T.J. and Holbrook, N.J. 2015. Projected changes to Tasman Sea eddies in a future climate. Journal of Geophysical Research: Oceans **120**: 7150-7165.

Parker, L., Ross, P. and O'Connor, W. 2011. Populations of the Sydney rock oyster, *Saccostrea glomerata*, vary in response to ocean acidification. Marine Biology **158**: 689-697.

Parker, L., Ross, P. and O'Connor, W. 2010. Comparing the effect of elevated pCO_2 and temperature on the fertilization and early development of two species of oysters. Marine Biology **157**: 2435-2452.

Parker, L., Ross, P. and O'Connor, W. 2009. The effect of ocean acidification and temperature on the fertilization and embryonic development of the Sydney rock oyster *Saccostrea glomerata* (Gould 1850). Global Change Biology **15**: 2123-2136.

Payne, N. L., Smith, J. A., van der Meulen, D. E., Taylor, M. D., Watanabe, Y. Y., Takahashi, A., Marzullo, T. A., Gray, C. A., Cadiou, G. and Suthers, I. M. 2016. Temperature dependence of fish performance in the wild: links with species biogeography and physiological thermal tolerance. Functional Ecology 30: 903–912.

Peters. R. and Raftos, D.A. 2003. The role of phenoloxidase suppression in QX-disease outbreaks among Sydney rock oysters (*Saccostrea glomerata*). Aquaculture **223**: 29 - 39.

Poloczanska, E. S., Brown, C.J., Sydeman, W.J., Kiessling, W., Schoeman, D.S., Moore, P.J., Brander, K., Bruno, J.F., Buckley, L.B., Burrows, M.T., Duarte, D.M., Halpern, B.S., Holding, J., Kappel, C.V., O/'Connor, M., Pandolfi, J.M., Parmesan, C., Schwing, F., Thompson,S.A. and Richardson, A.J.. 2013. Global imprint of climate change on marine life. Nature Climate Change **3**:919–925.

Ridgway, K.R. 2007. Long-term trend and decadal variability of the southward penetration of the East Australian Current. Geophysical Research Letters **34**: L13613.

Ruckelshaus, M., Doney, S.C., Galindo, H.M., Barry, J.P., Chan, F., Duffy, J.E., English, C.A., Gaines, S.D., Grebmeier, J.M., Hollowed, A.B. and Knowlton, N., 2013. Securing ocean benefits for society in the face of climate change. Marine Policy **40**: 154-159.

Sen Gupta, A., Brown, J.N., Jourdain, N.C, van Sebille, E., Ganachaud, A. and Vergés, A. 2015. Episodic and non-uniform migration of thermal habitats in a warming ocean. Deep Sea Research Part II: Topical Studies in Oceanography **113**:59-72.

Smale, D. A. and Wernberg, T. 2013. Extreme climatic event drives range contraction of a habitat-forming species. Proceedings of the Royal Society B: Biological Sciences **280**:2012-2829.

Suthers IM et al. (16 authors). 2011. The strengthening East Australian Current, its eddies and biological effects - an introduction and overview. Deep Sea Research-II. Topical Studies in Oceanography **58**: 538-546

Vergés, A., C. Doropoulos, H. A. Malcolm, M. Skye, M. Garcia-Piza, E. M. Marzinelli, A. H. Campbell, E. Ballesteros, A. S. Hoey, A. Vila-Concejo, Y. M. Bozec, and P. D. Steinberg. Long-term empirical evidence of ocean warming leading to tropicalization of fish communities, increased herbivory and loss of kelp. Proceedings of the National Academy of Sciences. In press.

Wernberg, T., Bennett, S., Babcock, R.C., de Bettignies, T., Cure, K., Depczynski, M., Dufois, F., Fromont, J., Fulton, C.J., Hovey, R.K., Harvey, E.S., Holmes, T.H., Kendrick, G.A., Radford, B.T., Santana-Garcon, J., Saunders, B.J., Smale, D.A., Thomsen, M.A., Tuckett, C.A., Tuya, F., Vanderklift, M.A. and Wilson, S.K. 2016. Climate-driven regime shift of a temperate marine ecosystem. Science **353**:169-172.