Date of Submission: 31-August 2012
Proposal Type: Working Group
Descriptive Title: Global Impacts of Climate Change on Kelp Forest Ecosystems
Short Title: Kelp & Climate Change

Working Group Leaders

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Project Summary

We propose a working group to examine the global impact of climate change on kelp forest ecosystems. Kelp forests are temperate and boreal rocky reefs dominated by macroalgae from the order Laminariales. Kelps currently dominate temperate nearshore ecosystems, covering 25% of the world's coastline (Steneck et al 2002, Cavanaugh Unpublished Data). They are critically important species, forming the foundation of many temperate and boreal coastal ecosystems (Dayton 1985). Anticipated change to kelps and their associated communities could have a large impact on the goods and services they provide. While individual impacts of extreme climate events have been explored at the regional or subregional level by many groups around the world (Scheibling & Lauzon-Guay 2010), we currently a unified global understanding of how the slower, longer-term environmental shifts from climate change will alter kelp forest communities globally. Furthermore, our current knowledge is often limited to kelps alone, or kelps and a few key grazers. Our working group will fill these gaps to provide a synthetic picture of how climate change will alter the future of kelp forests. Our efforts will thereby jumpstart a growing global network of kelp forest researchers (50+ and growing) to better coordinate efforts to forecast climate change's effects on kelp forests.

Towards that end, we propose three activities:

1) We will identify relevant abiotic impacts of climate change in each major kelp dominated biogeographic region. We will then perform a meta-analysis of experimental and observational studies to examine the impact of predicted abiotic changes on kelps, other dominant space-holders, herbivores, and predators.

2) We will create a unified global database of all extant kelp community monitoring data sets. We will use these to model the direct and indirect impacts of changes in climate on community structure and function and highlight local deviations from global trends.

3) We will create a global database of species interaction networks for all kelp dominated regions. We will use results from our meta-analysis and detection of global trends to examine how extinctions, invasions, and more subtle changes in the abundance of different species or guilds of species will alter future network structures.

Proposed Start and End Dates: 11/2012 through 11/2013
Proposed Data Release Date: 11/2013
Is this a resubmission? No
Conflicts of Interest: None

Problem Statement

Predicting global impacts of climate change has become one of the central goals of applied ecology. Roughly one quarter of the world's shorelines are dominated by kelps (Figure 1, Steneck et al 2002, Cavanaugh Unpublished Data). Kelps can be particularly sensitive to shifts in climate as their productivity is linked to seawater nutrient concentrations, temperature (Gagne et. al 1982), and wave energy (Byrnes et al. 2011). Yet we lack a comprehensive understanding of how these highly productive and diverse ecosystems (Mann 1973, Dayton 1985) will respond to climate change. Existing knowledge of climate impacts is largely based on short-term extreme climate events (e.g., Wernberg et al. 2012) or sudden shifts related to crossing environmental tipping points (Ling et al. 2008). From these studies, several principles emerge.

- *Changes in kelp physiological rates can change species ranges, local competitive hierarchies, and resilience to disturbance.*

- *Shifts in behavior and ranges by temperature-sensitive species at higher trophic levels can have large direct and indirect impacts on kelp forest community structure. These shifts often interact with other human-driven disturbances.*

- *Climate impacts on kelp forests extend beyond changes in water temperature, but extend to shifts in disturbance regimes from storms, depletion of dissolved nutrients, and exacerbation of impacts from other climatic events such as El Niño or the Pacific Decadal Oscillation.*

These conclusions arise from regional studies. We do not know how much they apply to kelp forests around the globe. They are qualitative. We do not have a quantitative understanding of the relative importance of changes in temperature, nutrients, storm disturbance, CO_2 levels, or sea ice extent, nor how they interact. For example, wave disturbance cancels out the effects of warming in Norwegian kelp beds (Andersen 2011). Impacts may also vary between regions - Western Australian waters are warming (Wernberg et al. 2011) while South African waters are cooling (Bolton et al. 2012). We also lack a comprehensive picture of indirect effects of climate change as they radiate through kelp forest interaction networks. Indirect effects may alter the simple conclusions that can be drawn from the above three points.

We need to create a synthetic understanding of the current and future impacts of climate change on kelp forests. The general principles above are built from a growing number of studies for which the data are available for synthesis. Additionally, researchers have collected decades of monitoring data, containing valuable information on local changes in climate drivers and community shifts (e.g., Moy and Christie 2012) These datasets have not been combined, and remain underutilized. Together, these two powerful data streams can be used to build a global understanding of climate change impacts in kelp forests.

Here we propose to synthesize global information in order to predict how climate will impact kelp forests. To do so, we will address three major questions.

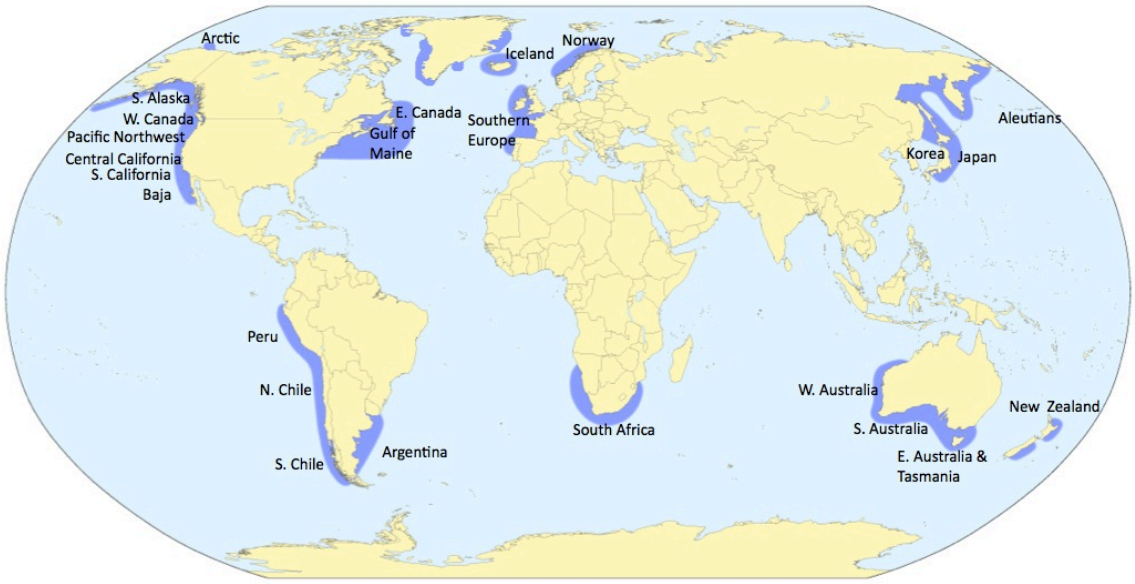

Figure 1: A global map of kelp distribution with regions represented by members of our working group and extended network highlighted. Kelp distributions interpolated from maps by Steneck et al. 2002, the Ocean Biogeographic Information System, and the Global Biodiversity Information Facility.

Proposed Activities

Question 1 - What are the documented consequences of global and regional shifts in climate to kelp forests?

To answer this question, we will first identify the relevant regional and global abiotic shifts in these systems. Second, we will synthesize the literature via a meta-analysis of experimental and observational studies that have investigated the impacts of these abiotic drivers of community structure.

Task 1a: Detecting trends in records of abiotic measurements. For each study region, we will assemble records of temperature, storm frequency & intensity, wave height, and dissolved nitrate concentrations. We will use auto-regressive state-space models (Ives et al. 2003) to detect regional trends and parse out variation due to local and seasonal influences. The results will be assembled to build a climate impact map for temperate ecosystems to understand threats to kelp forest ecosystems. We will combine this information with projections of future climate change (IPCC AR4) to understand the most relevant impacts to each region.

Task 1b: Meta-analysis of climate impacts. We will perform a meta-analysis of experimental and observational studies that explores the impacts of the above abiotic changes on kelps, grazers, and their predators. Specifically, we will test the effects of abiotic drivers on recruitment, growth, resource use, and species interaction strength.

Mixed-effects models will be used to explore the general and region-specific effects of abiotic drivers on populations. Together with the abiotic trends (Task 1a), the results of the meta-analysis will enable predictions of how key species and their interactions will change in the future.

Question 2 - How have kelp communities around the globe changed over the past several decades?

Scientists have surveyed kelp forests for decades (Table 1). Many of these records have formed the backbone of multiple publications (e.g., Davis et al 1997) or provided information for policy-makers (e.g. Sugar Kelp in Southern Norway from NIVA), while others have remained largely unpublished (Estes's San Nicholas Island Data). Some data sets span decades (Steneck et al. in Maine from 1975-Present), and each is an incredible resource in its own right. Brought together, what story will they tell us about how kelp forests have changed over the years due to climate change?

Task 2a: Building a Global Kelp Forest Community Monitoring Database. We propose to assemble extant data sets into a single cross-comparable data product. The publicly accessible platform will allow users to examine the results of individual monitoring efforts, or to access an integrated global data set where measurements have been standardized between surveys. Furthermore, it will be built so that other scientists can easily upload their own data. Thus, it will form the basis of a platform for the future of kelp forest research beyond just this working group. Much of the initial data that will populate this product (Table 1-3) has been collected by working group participants or the participants of our larger kelp forest and climate change network (Table 4).

Task 2b: Exploration of long-term trends in kelp forest communities We will analyze the database to explore long-term trends in whole kelp forest communities and the signal of climate impacts as identified in Question 1. We will use Multivariate Autoregressive State-Space models (Ives et al. 2003) and Structural Equation Models (Grace et al. 2010) to tease out 1) long-term trends in kelp forest communities independent of climate change, 2) temporal and seasonal trends independent of long-term environmental signals, 3) direct effect of abiotic drivers identified in Question 1, 4) indirect effects propagating within or between trophic levels (Figure 2). The code used for these analyses - from data accession to final model results - will all be open-access so that they may be re-run in the future as the database is updated. This effort would represent the first of its kind to identify global long-term patterns in kelp forest communities. Its results will be extremely informative, independent of our focus on climate change.

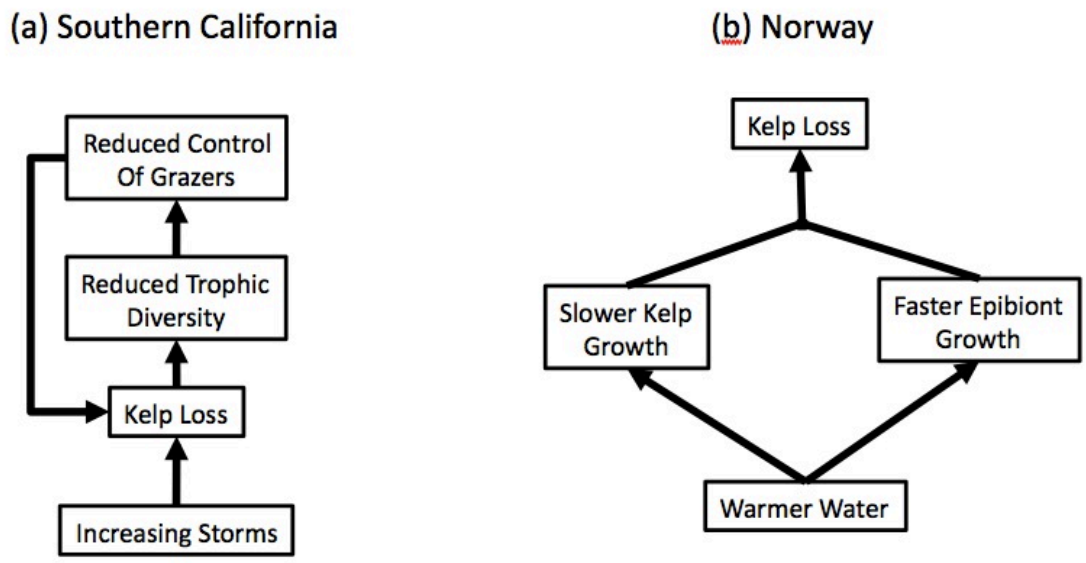

Figure 2: Two example of the combination of the potential direct and indirect cascading effects of climate change in different kelp forest ecosystems. (a) Increasing severe storm frequency in Southern California can lead to kelp loss and reduced trophic diversity which can hinder kelp recover (after Byrnes et al. 2006, Byrnes et al. 2011). (b) In Norway, warmer water both slows kelp growth and speeds epibiont growth. This might lead to overgrowth of kelp by epibiont that could be a cause of major observed kelp die offs (after Anderson et al. 2011).

Question 3 - How might the effects of climate change cascade through kelp forest interaction networks to indirectly alter these ecosystems?

One reason for regional differences in the biological impacts of climate change is biogeographic variation in interaction network structure. Kelp forests are well known for indirect interactions resulting from species removals (Estes and Palmisano 1974). Similarly, species additions due to climate-driven range shifts have caused similar cascades of indirect interactions (Ling et al. 2009). How would the loss or gain of key species in kelp forest interaction networks lead to long-term shifts in the community? How will regional variation in network structure alter these indirect effects?

Task 3a: Assembly of regional kelp forest species interaction networks. One of our working group leaders, M. Novak, has been part of a team of researchers building a literature-based MySQL database of species' life histories and interactions for Eastern Pacific kelp forests. The publicly accessible online interface (http://kelpforest.ucsc.edu) has enabled the team to capitalize on numerous registered users interested in learning about kelp forests by permitting them to enter, and instantaneously visualize, data through guided readings of the literature.

We propose to extend this database beyond the Eastern Pacific. Our participants will work with their local undergraduates to search both the white and grey literature and

assemble a list of species interactions in each biogeographic region. This information will be publicly available. We will then use it for our analyses examining the consequences of regional differences in the species interaction networks.

Task 3b: Network analysis of changes in interaction structure. We will use network analysis to examine how the deletion or addition of key species (e.g., kelp, herbivore, predator) propagates to other trophic levels (Dunne et al. 2002). We will compare patterns of extinctions & creation of empty niches when species randomly removed to removals matching species' sensitivity to climate change as determined by Q1. These analyses should yield a wide range of predictions about how different aspects of climate change may shift community structure. From these predictions, we will characterize which regional systems are more susceptible to a cascade of indirect interactions resulting from climate change versus those that, though they should experience strong direct impacts, are resilient to additional indirect impacts.

Participants - The following is a table of participants for the course of the three working group meetings. In each meeting, we are limiting the number of participants to 15 or less, depending on the specific meeting goals (e.g., K. Cavanaugh's GIS expertise means he may only be needed for meeting 1). Members of our network from other regions (Table 4) will participate remotely as needed, either contributing to plenary or being available for data and natural history consultation. All listed personnel are committed to participating. Two slots are still to be filled by meeting one. One is a graduate student we are recruiting from an Information Sciences program for whom the challenges of the database will form part of their thesis research.

Name	**Affiliation**	**Expertise (technical or regional)**
Jarrett Byrnes	Asst Professor, UMass Boston	Gulf of Maine, Southern California, SEM
Sean Connell	Professor, University of Adelaide	Southern Australia
Mark Novak	Asst Professor, Oregon State	Central California & Oregon, Network Analysis, NCEAS technical liason
TBD	Graduate Student	Information Scientist and Database Developer
Kyle Cavanaugh	Postdoc, UC Santa Barbara	GIS & Remote Sensing of Kelps
Anne Salomon	Asst Professor, Simon Fraser University	Multivariate Autoregressive Modeling, Southern California & Western Canada

John Bolton	Professor, University of Cape Town	South Africa
Thomas Wernberg	Assoc Professor, University of Western Australia	Western Autralia
Scott Ling or Craig Johnson	University of Tasmania	Eastern Australia/Tasmania
Alejandro Perez Matus	Assi Prof, University of Valparaiso	Chile
Kira Krumhansl	Postdoc, Dalhousie University	Eastern Canada
Kjell-Magnus Nordhaug	Researcher, Norwegian Institute for Water Research	Norway
Isabel Sousa Pinto	Professor, University of Porto	Europe
Andrew Rassweiler	Researcher, UC Santa Barbara	Southern California
Kwang Young Kim	Professor, Chonnam National University	Korea
Brenda Konar	Professor, University of Alaska Fairbanks	Arctic/Alaska
Nick Shears	Senior Lecturer, University of Auckland	New Zealand
Fiorenza Micheli	Stanford University	Baja, Meta-analysis
TBD	Graduate Student from One region	

Timetable

We will hold three 5-day meetings (11/12, 5/13, 11/13). Prior to our first meeting,

participants will be asked to perform one of the following: 1) Identifying sources of environmental data. 2) Identifying the regional literature regarding the impacts we are exploring in Task 1a. Participants will bring relevant literature databases to the meeting so that we can harvest data for the meta-analysis at the first working group meeting. 3) Obtaining raw data from the sources listed in Table 1 or other sources identified before our first meeting. 4) Identifying a team of undergraduate students who will participate in the construction of regional food web databases. During meeting one we will orient each other to the natural history of our different systems, begin tackling Q1, set up a team to build the monitoring database, and teach everyone how to interact with the database of species life histories and interactions so that they can take it home and begin working with undergraduates to build regional food webs. During meeting two we will finalize analyses from Q1, launch the monitoring database and begin analyzing outputs for Q2, and begin analyses of the regional food webs based on results from Q1. During meeting three, we will finalize analyses and papers from Q2 and Q3.

Anticipated Results and Beneficiaries

As this work will create the first truly global understanding of climate change impacts on kelp forest ecosystems, we hope to publish papers from our efforts in high profile journals such as PNAS, Nature, and Science. We expect to publish one to two narrative or data papers for each question. Moreover, our work will guide the efforts of our nascent network of scientists interested in creating a global experimental and monitoring network to evaluate climate impacts in kelp forest ecosystems, of which we are members (Table 4). The databases we create here will form the linchpin of future work on kelp forests and climate change. We plan on using and improving them after beyond this working group. Beyond our group, these databases of kelp forest monitoring programs and regional food web structure will provide an invaluable resource for anyone studying these ecosystems around the globe. They will be used by the developing international effort, GEO BON – the Global Earth Observation, Biodiversity Observation Network, of which one of our network members is the chair of the working group on Marine Ecosystem Changes. Furthermore, our analyses of regional differences in climate impacts will guide the development of local research programs in climate change not just in kelp forest ecosystems, but also in temperate marine ecosystems and will be useful to anyone studying or making planning decisions in marine coastal ecosystems.

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Table 1: Data sets gathered by working group thus far, their temporal extent, and number of sites per region.

Biogeographic Region Covered	Name of Data Set	Person or Organization Collecting the Data	Years Sampled	Number of sites
Alaska	Kachemak Bay Alaska	Brenda Konar and Katrin Iken	2003 to present	3-4
Alaskan Beaufort Sea	Beaufort Sea Arctic Kelp Communities	Ken Dunton	1978-present	12
Aleutians	NPRB	Jim Estes	2006-9	~560 sites on 36 islands
Atlantic coast of Nova Scotia	Nova Scotia kelp population measurements	Dalhousie University, Dr. Robert Scheibling	1968-2012	1-11 sites, locations differing in some cases per sampling event
Australia	West Island	Sean Connell	2001	90
Australia	Trans Australia kelp	Thomas Wernberg	2011-2012	36 (9 in each of 4 regions)
Australia, Western	West coast kelps	Thomas Wernberg	2006-present	9-12
Austrlia	Reef Life Survey	Reef Life Survey Foundation Incorporated	2008-present	variable (>1,000 sites total, but subsets sampled annually)
Beaufort Sea from Barrow to Kaktovik	Beaufort Sea	Brenda Konar and Katrin Iken	2003 to present	13 but sampling at each is variable in time
California to Baja California, MEX	Landsat canopy biomass	Kyle Cavanaugh	1984-2011	complete coverage of coast at 30 m resolution
California-Oregon	PISCO community survey	Jenn Caselle/Mark Carr	1998-Present	approx 80
Central-Northern Chile	Fondecyt Grant	Alejandro Perez Matus	2009-Present	10
Gulf of Maine	Gulf of Maine Monitoring	Jon Witman	1979-Present	19

Biogeographic Region Covered	Name of Data Set	Person or Organization Collecting the Data	Years Sampled	Number of sites
Gulf of Maine, Boreal/Subarctic	Maine kelp forests	Robert Steneck	1975 - 2010	20
Northeastern New Zealand	Hauraki Gulf shallow reef monitoring	Nick Shears, University of Auckland	1999-2012	~40
Northern Chile	Fondecyt Grant 1040425	Julio Vasquez	2004-2008	4
Northern BC, Canada	Haida Gwaii	Salomon Lab	2009-2012	9
Northern California Channel Islands	Channel Islands National Park Monitoring Data	Channel Islands National Park	1981 to present	presently 33 (originally 13)
Northern Gulf of St. Lawrence, Québec, Canada	Mingan Islands	Patrick Gagnon (Memorial University)	1983, 1988, 1999, 2004	1000s (aerial survey)
Northern Japan	Monitoring Sites 1000 Coastal Monitoring Program	Ministry of Environment, Japan	2008-Present	6
Northern Norway (64*N and 71*N)	Restore	NIVA	2008-2009	12
Punta Eugenia, Baja California, Mexico	Isla Natividad marine reserve monitoring	Andrea Saenz-Arroyo, Comunidad y Biodiversidad, and Fishing Cooperative "Buzos y Pescadores"	2006-2012	5 areas, ~ 20 transects/area
Skagerrak	KYS Sugar kelp monitoring programme	NIVA	2009-Present	12
Skagerrak, North Sea	KYO Coastal monitoring	NIVA	1990-Present	16
South Africa	Andre Share kelp monitoring data	Andre Share	1996-1997	9

Biogeographic Region Covered	Name of Data Set	Person or Organization Collecting the Data	Years Sampled	Number of sites
South Africa	Field et al 1980	kelp bed project	late 1970s	6
South Africa	Mapping S African kelp resources	Rob Anderson	1993, 1996, 2005	Entire West Coast
Southern Australia	Southern Australian MPA and biodiversity surveys	Neville Barrett/Graham Edgar	2002-Present	800
Southern Australia (Tasmania)	Tasmanian MPA dataset	Neville Barrett/Graham Edgar	1992-2012	27 current & 45 in the past decade
Southern California Bight	Pt. Loma Kelp Forest	Scripps Kelp Ecology Group	1983-Present	NA
Southern California Bight	SBC LTER Long-Term Kelp Forest Monitoring	Santa Barbara Coastal LTER	2000-Present	35
Southern California, Channel Islands.	San Nicolas Island	Jim Estes, USGS; Mike Kenner, USGS; Tim Tinker, USGS	1981-Present	6
Southern Chile	Southern Chile	Alejandro H. Buschmann	2007-Present	3
Southwestern Australia	Perth historical kelp	Thomas Wernberg	1978-Present	2 to 20
SW South Africa	Hangklip/Bettys Bay data 1997-1999	Rob Anderson	1997-1999	2
SW South Africa	J. Jackelman MSc data	Rob Anderson	1989-1990	4 site x 3 depth zones
SW South Africa	SA Gansbaai kelp data	Rob Anderson	1992-1994	2
Tasmania, Southern Australia	Lap of Tasmania	IMAS, University of Tasmania	1992-5 and 2006-7	136

Biogeographic Region Covered	Name of Data Set	Person or Organization Collecting the Data	Years Sampled	Number of sites
Temperate Australia (WA, SA, NSW)	Herbivory Australia	Thomas Wernberg	2004-2005	27
West Coast Vancouver Island, Canada	Vancouver Island otter invasion	Jane Watson	1987-present	8

Table 2: Physical measurements related to climate change and measurements of kelp abundance for each data set.

Name of Data Set	Temperature	Wave Height	Nutrients	Light	pH	Salinity	Kelp Density	Kelp Size	Kelp Biomass	Kelp % Cover	GIS Kelp Cover
Kachemak Bay Alaska	x						x		x		
Beaufort Sea Arctic Kelp Communities	x			x		x	x		x		
NPRB							x			x	
Nova Scotia kelp population measurements	x	x					x			x	
West Island	x						x	x			
Trans Australia kelp	x	x	x	x			x	x	x		
West coast kelps	x	x	x	x			x		x	x	
Reef Life Survey	x									x	
Beaufort Sea	x					x	x		x		
Landsat canopy biomass	x	x									x
PISCO community survey	x					x	x				

Name of Data Set	Temperature	Wave Height	Nutrients	Light	pH	Salinity	Kelp Density	Kelp Size	Kelp Biomass	Kelp % Cover	GIS Kelp Cover
Fondecyt Grant	x						x	x	x		
Gulf of Maine Monitoring	x	x					x				
Maine kelp forests	x			x						x	
Hauraki Gulf shallow reef monitoring							x			x	
Fondecyt Grant 1040425	x		x				x				
Haida Gwaii	x						x		x		
Channel Islands National Park Monitoring Data	x						x	x			
Mingan Islands										x	
Monitoring Sites 1000 Coastal Monitoring Program										x	
Restore							x				
Isla Natividad marine reserve monitoring	x				x		x		x		

Name of Data Set	Temperature	Wave Height	Nutrients	Light	pH	Salinity	Kelp Density	Kelp Size	Kelp Biomass	Kelp % Cover	GIS Kelp Cover
KYS Sugar kelp monitoring programme										x	
KYO Coastal monitoring	x		x							x	
Andre Share kelp monitoring data							x	x	x		
Field et al 1980	x						x		x		
Mapping S African kelp resources											x
Southern Australian MPA and biodiversity surveys	x									x	
Tasmanian MPA dataset										x	
Pt. Loma Kelp Forest	x						x		x		
SBC LTER Long-Term Kelp Forest Monitoring		x					x		x		
San Nicolas Island							x				
Southern Chile					x			x			

Name of Data Set	Temperature	Wave Height	Nutrients	Light	pH	Salinity	Kelp Density	Kelp Size	Kelp Biomass	Kelp % Cover	GIS Kelp Cover
Perth historical kelp	x						x		x	x	
Hangklip/Bettys Bay data 1997-1999	x						x	x			
J. Jackelman MSc data	x						x			x	
SA Gansbaai kelp data							x		x		
Lap of Tasmania	x									x	
Herbivory Australia							x				
Vancouver Island otter invasion							x				

Table 3: Other taxonomic groups sampled by data sets gathered by the working group thus far and current state of public accessibility of data sets. Note, members have access to all of the data sets listed here. We are exploring these and additional data sets for the working group.

Name of Data Set	Other algae	Sessile Invertebrates	Urchins	Other Mobile Invertebrates	Fish	Currently Public?	Contact Available?	Is contact a network member?
Kachemak Bay Alaska	x	x	x	x	x	No	yes	yes
Beaufort Sea Arctic Kelp Communities	x		x	x		Yes		
NPRB			x			No	yes	no
Nova Scotia kelp population measurements	x	x	x	x		No	yes	yes
West Island	x		x		x	No	yes	yes
Trans Australia kelp			x		x	No	yes	yes
West Coast kelps	x	x	x	x	x	No	yes	yes
Reef Life Survey			x	x	x	No	yes	yes
Beaufort Sea	x	x	x	x	x	No	yes	yes
Landsat canopy biomass						Yes		

Name of Data Set	Other algae	Sessile Invertebrates	Urchins	Other Mobile Invertebrates	Fish	Currently Public?	Contact Available?	Is contact a network member?
PISCO community survey	x	x	x	x	x	Yes		
Fondecyt Grant	x			x	x	No	yes	yes
Gulf of Maine Monitoring	x		x			No	yes	yes
Maine kelp forests	x		x			No	yes	yes
Hauraki Gulf shallow reef monitoring	x	x	x			No	yes	yes
Fondecyt Grant 1040425	x	x	x	x	x	No	yes	yes
Haida Gwaii			x	x	x	Yes		
Channel Islands National Park Monitoring Data	x	x	x	x	x	Yes		
Mingan Islands						No	yes	no
Monitoring Sites 1000 Coastal Monitoring Program	x					Yes		
Restore			x			No	yes	yes

Name of Data Set	Other algae	Sessile Invertebrates	Urchins	Other Mobile Invertebrates	Fish	Currently Public?	Contact Available?	Is contact a network member?
Isla Natividad marine reserve monitoring	x		x	x	x	No	yes	no
KYS Sugar kelp monitoring programme	x	x	x	x	x	No	yes	yes
KYO Coastal monitoring	x	x	x	x	x	No	yes	yes
Andre Share kelp monitoring data						No		
Field et al 1980		x		x	x	Yes		
Mapping S African kelp resources						Yes		
Southern Australian MPA and biodiversity surveys			x	x	x	No	yes	yes
Tasmanian MPA dataset			x	x	x	No	yes	yes
Pt. Loma Kelp Forest	x	x	x	x		No	yes	yes
SBC LTER Long-Term Kelp Forest Monitoring	x	x	x	x	x	Yes		

Name of Data Set	Other algae	Sessile Invertebrates	Urchins	Other Mobile Invertebrates	Fish	Currently Public?	Contact Available?	Is contact a network member?
San Nicolas Island	x	x	x	x	x	No	yes	no
Southern Chile			x	x		No	yes	yes
Perth historical kelp	x	x	x	x	x	No	yes	yes
Hangklip/Bettys Bay data 1997-1999	x		x	x		Yes		
J. Jackelman MSc data	x	x	x	x	x	Yes		
SA Gansbaai kelp data	x		x	x		Yes		
Lap of Tasmania	x		x	x	x	No	yes	yes
Herbivory Australia			x		x	No	yes	yes
Vancouver Island otter invasion			x			No	yes	yes

Table 4: List of participants in the Climate And Kelp Ecosystem Studies Network.

Biogeographic Region	Name	Affiliation
Alaska/Arctic	Brenda Konar	University of Alaska Fairbanks
Arctic	Ken Dunton	University of Texas at Austin
Australia	Sean Connell	University of Adelaide
Australia	Thomas Wernberg	University of Western Australia
Australia	Bayden Russell	University of Adelaide
Australia & Tasmania	Graham Edgar	University of Tasmania
Australia & Tasmania	Neville Barrett	University of Tasmania
Australia & Tasmania	Rick Stuart-Smith	University of Tasmania
Baja	Fiorenza Micheli	Stanford University
Baja	Matt Edwards	San Diego State University
British Columbia	Julia Baum	University of Victoria
British Columbia	Rebecca Martone	University of British Columbia
British Columbia	Anne Salomon	Simon Fraser University
British Columbia	Jane Watson	University of Victoria
California & North	Jenn Caselle	University of California Santa Barbara
Central California	Mike Graham	Moss Landing Marine Laboratory
Central Chile	Alejandro Perez Matus	Universidad de Valparaiso
Central Coast/Oregon	Mark Novak	Oregon State University
Chile	Alejandro Buschmann Rubio	Universidad de Los Lagos
Eastern Atlantic	Isabel Sousa Pinto	University of Porto
Eastern Canada	Robert Scheibling	Dalhousie University
Eastern Canada	Kira Krumhansl	Dalhousie University
Global	Kyle Cavanaugh	University of California Santa Barbara
Gulf of Maine	Jarrett Byrnes	University of Massachusetts Boston
Gulf of Maine	Robert Steneck	University of Maine
Gulf of Maine	Jon Witman	Brown University

Biogeographic Region	Name	Affiliation
Gulf of St. Lawrence	Ladd Johnson	University of Laval
Ireland	Nessa O'Connor	Queen's University Belfas
Ireland	Christine Maggs	Queen's University Belfast
Japan	Masahiro Nakaoka	Hokkaido University
Korea	Kwang Young Kim	Chonnam National University
New Zealand	Nick Shears	University of Auckland
Norway	Guri Sogn Andersen	University of Oslo
Norway	Camilla With Fagerli	Norwegian Institute for Water Research
Norway	Kjell Magnus Norderhaug	Norwegian Institute for Water Research
Norway	Frithjof Moy	Institute of Marine Research, Norway
Peru	Patricia Gil	La Molina
San Diego	Ed Parnell	University of California San Diego
Southern California	Andrew Rassweiler	University of California Santa Barbara
Southern California	Dan Reed	University of California Santa Barbara
South Africa	John Bolton	University of Cape Town
South Africa	Robert Anderson	University of Cape Town
Sweden	Johan Eckloff	University of Stockholm
Sweden	Göran Nylund	University of Gothenburg
Tasmania	Scott Ling	University of Tasmania
Tasmania	Craig Johnson	University of Tasmania
Washington	Robin Elahi	Friday Harbor Laboratories
Washington	David Duggins	Friday Harbor Laboratories
Washington / Gulf of Maine	Ken Sebens	Friday Harbor Laboratories

Jarrett Edward Kaplan Byrnes

Department of Biology, University of Massachusetts Boston
100 Morrissey Blvd; Boston, MA 02125
Phone: 401.529.4104 Email: jarrett.byrnes@umb.edu
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Education:

2002-2008 UC Davis, Population Biology, M.S. 2003, Ph.D. 2008
1997-2001 Brown University, Bachelor of Science in Biology

Appointments:

2012 - Present Assistant Professor, University of Massachusetts Boston
2010 - 2012 Postdoctoral Fellow, National Center for Ecological Analysis and Synthesis
2008 - 2010 Postdoctoral Fellow, Santa Barbara Long Term Ecological Research Project

Research Summary:

My research focuses on the causes and consequences of food web complexity. In particular, I focus on climate change effects on both kelp forests and fouling community I am interested in how human driven global environmental change will affect the function of ecosystems by altering the diversity and structure of food webs in these systems. I use small-scale experimental techniques coupled with the statistical modeling of large-scale long-term datasets to bridge the gap between microecological mechanisms and macroecological patterns.

Five Publications Relevant to This Proposal

Byrnes, J.E.K., Cardinale, B.J., and Reed, D.R. Sea urchin grazing increases with prey diversity on temperate rocky reefs. *Ecology*.

Fox, J., **Byrnes, J.**, Boker, S., and Neale, M. In Press. Structural equation modeling in R with the *sem* and *OpenMX* packages. In *Handbook of Structural Equation Modeling*. Rick H. Hoyle, David Kaplan, George Marcoulides, and Steve West, eds.

Byrnes, J.E., Reed, D.C., Cardinale, B.J., Cavanaugh, K.C., Holbrook, S.J., and Schmitt, R.J. 2011. Climate driven increases in storm frequency simplify kelp forest food webs. *Global Change Biology*. 17: 2513-2524. [doi]

Hughes A.R., **Byrnes J.E.**, Kimbro D.L. & Stachowicz J.J. 2007. Reciprocal relationships and potential feedbacks between biodiversity and disturbance. *Ecology Letters*. 10: 849-864.

Byrnes, J.E., Stachowicz, J.J., Hultgren, K.M., Hughes, A.R., Olyarnik, S.V., Thornber, C. 2006. Predator Diversity Enhances Trophic Cascades in Kelp Forests by Modifying Herbivore Behavior. *Ecology Letters*. 9: 61-71.

Five Additional Publications

Hooper, D.U., Adair, E.C., Cardinale, B.J., **Byrnes, J.E.K.**, Hungate, B.A., Matulich, K.L., Gonzalez, A., Duffy, J.E., Gamfeldt, L., O'Connor, M.I. 2012. Biodiversity loss ranks as a major driver of ecosystem change. *Nature*.

Cardinale, B.J., Matulich, K., Hooper, D.U., **Byrnes, J.E.**, Duffy, E., Gamfeldt, L., Balvanera, P., O'Connor, M.I., Gonzalez, A. 2011. The functional role of producer diversity in ecosystems. *American Journal of Botany*. 98: 572-592.

Byrnes, J.E. and Stachowicz, J.J. 2009. The consequences of consumer diversity loss: different answers from different designs. *Ecology*. 90: 2879-2888.

Byrnes, J.E. and Stachowicz, J.J. 2009. Short and Long Term consequences of increases in exotic species richness on water filtration by marine invertebrates. *Ecology Letters*. 8: 830-841.

Byrnes, J.E., Reynolds, P.L., Stachowicz, J.J. 2007. Invasions and extinctions reshape coastal marine food webs. *PLoS One*. 2: e295.

Software:

Lavaan - Analysis of latent variable structural equation models in R. Contributing Developer. http://lavaan.org

The sem.additions library – Methods for the simple model manipulation, multimodel inference, and correcting for non-normality in the analysis of structural equation in R. http://r-forge.r-project.org/projects/sem-additions/

Synergistic Activities & Working Groups

2011-2012. Determinants of extinction in ancient and modern seas. National Evolutionary Synthesis Center working group.

2011-2012. The #SciFund Challenge. A large-scale effort to attempt to get scientists to engage the public by crowdfunding their research. http://scifund.rockethub.com for projects and http://scifund.wordpress.com for the project blog. Projects raised $175,000 to date.

2010-2011. Biodiversity and the functioning of ecosystems: translating results from model experiments to functional reality. National Center for Ecological Analysis and Synthesis working group.

2010. Dissertation Initiative for the advancement of Climate Change ReSearch (DISCCRS) participant. Interdisciplinary workshop in climate change communication.

Invited Presentations (Last Three Years)

2011. Consequences of climate driven shifts in kelp forest food web complexity. Romberg Tiburon Center for Environmental Studies. Hopkins Marine Lab

2011. Beyond species richness: food web structure and ecosystem function. World Conference on Marine Biodiversity.

2011. Causes and consequences of ecological complexity. Stony Brook University. Northeastern University. Universidad Nacional Autónoma de México, Morelia.

2010. Giving a great talk: How to use your body and your voice. With Lila Rose Kaplan and Anne Torsiglieri. Kavli Institute for Theoretical Physics.

2010. Causes and consequences of biodiversity in southern Californian kelp forests. National Center for Ecological Analysis and Synthesis. San Diego State University Ecology and Evolutionary Biology Seminar Series. University of California Santa Barbara EEMB Seminar Series.

CURRICULUM VITAE – Professor SEAN D. CONNELL

POSITION: ARC FUTURE FELLOW and PROFESSOR
School of Earth and Environmental Sciences
University of Adelaide
BIRTH 17TH June, 1966
WEB: http://www.marinebiology.adelaide.edu.au/people/staff/sean.html

ACADEMIC QUALIFICATIONS

Ph.D. **University of Sydney** (1995) Thesis: "The contribution of large predatory fish to the mortality and abundance of juvenile coral reef fish". I published 10 papers from this thesis.

M.Sc. University of Auckland (1991) Thesis: "The population ecology of *Forsterygion varium*: The roles of recruitment and postrecruitment processes". Awarded First Class Honours for thesis and published one paper (>150 citations).

B.Sc. **University of Canterbury** (1989). Awarded 'A Bursary' for high pass rate.

PRIZES, AWARDS and FELLOWSHIPS

2009 ARC Future Fellowship of Australian Research Council
2009 Faculty of Science Mid-Career Research Excellence Award, University of Adelaide
2004 The J.G. Russell award for excellence in research by the Australian Academy of Science
2004 ARC Queen Elizabeth II Fellowship for highly ranked (top 10%) of Australian Research Council submission for Australian Research Fellowship.
2003 The Andrewartha Medal for outstanding contribution to ecology by a young Australian.
1994 First prize for best student talk at the joint marine sciences (ACRS/AMSA/ISRS) conference, Townsville.
1991 University of Sydney Postgraduate Research Scholarship.
1989 New Zealand University Grants Committee Postgraduate Scholarship. Offer declined.

Research

RESEARCH PUBLICATIONS: 104 publications, including 10 book chapters and one book
I have a total of 104 publications including 93 peer-reviewed publications including 'in press', one edited book, 10 book chapters. Each ISI listed publication is cited an average of 24-25 times. Over the last 5 years they have been collectively been cited at an average rate exceeding 200 cites/year. My citation rate per paper is within the top 10-15% of the fields of 'Plant and Animal Science' and 'Environmental/Ecology' over the last 10 years (ISI Essential Science Indicators). My *h*-index is 30.

More than half of my publications of the last 5 years are ranked A* or A by Excellence in Research for Australia (ERA), with the remaining ranked B (one journal is yet to be listed by ARC). My latest ARC assessors comments stated that 'with over 40 publications over the past 5 years in a range of high-quality and prestigious journals' (Assessor C) and that my 'publication record in high standing journals is remarkable' Assessor B).

RESEARCH FUNDING: 9 competitive grants all as senior CI, including 6 nationally competitive grants ($2,542,000) as an employee of The University of Adelaide.

My research focus on the origin, maintenance and threats to coastal habitats and has been driven by continuous reflection and review as to what are the major questions in fundamental biological terms as well as the key management needs. My approach has been to investigate these in the most rigorous and effective fashion, utilising collaborations to bring the best intellectual and physical resources nationally and internationally to bear. Global Climate Change is now an unavoidable issue for the ecological sciences for which my laboratory has embraced.

SUPERVSION, TRAINING, TEACHING & SERVICE

Lead supervision of post-doctoral, doctoral and BSc (Honours) research at University of Adelaide includes 6 post-doctoral positions, 9 PhD completions and 33 BSc (Honours completions).

Editor for 'Marine Biology'
Regional Editor for 'Marine Biology' (Springer-Verlag), an international journal for marine biologists.

Organisation of Symposia
Principle organiser for international conference in 2009 (International Temperate Reefs Symposia)

Advisory Committees to Federal and Sate Government
2005 – present The scientific working group for Marine Protected Areas. Appointed by the Minister of Environment and Conservation of SA.
2006-2007 Chair of the Technical Reference Group "Resource condition indicators for South Australia coast'.
2002-2007 The Great Australian Bight Management Committee. Appointed by the Commonwealth (Australian Fisheries Management Authority).

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Education:

Cornell University, B.A. Biology, *2000*.
University of Chicago, M.S. Ecology and Evolution, *2005*.
University of Chicago, Ph.D. Ecology and Evolution, *2008*.

Appointments:

Oregon State University, Assistant Professor, *2012-present.*
University of California at Santa Cruz, Postdoc, *2009-2012*.

5 publications most closely related to the proposed project (chronological):

Novak, Wootton, Doak, Emmerson, Estes & Tinker (2011). Predicting community responses to perturbations in the face of imperfect knowledge and network complexity. *Ecology* 92(4): 836-846 (*Concepts & Synthesis*). **Highlighted by Faculty of 1000**

Yeakel, Stiefs, Novak & Gross (2011). Generalized modeling of ecological population dynamics. *Journal of Theoretical Ecology* 4(2): 179-194. **Highlighted by Faculty of 1000**

Novak (2010). Estimating interaction strengths in nature: experimental support for an observational approach. *Ecology* 91(8): 2394-2405.

Novak & Wootton (2010). Using experimental indices to quantify the strength of species interactions. *Oikos* 119: 1057-1063 (*Forum*).

Novak &Wootton (2008). Estimating nonlinear interaction strengths: an observational method for species-rich food webs. *Ecology* 89(8): 2083-2089 (*Report*).

5 additional significant publications (chronological):

Twardochleb, Novak & Moore (2012). Using the functional response of a consumer to predict biotic resistance to invasive prey. *Ecological Applications* 22(4): 1162–1171.

Tinker, Guimarães, Novak, Marquitti, Bodkin, Staedler, Bentall & Estes. (2012). Structure and mechanism of diet specialisation: testing models of individual variation in resource use with sea otters. *Ecology Letters* 15(5): 475-483.

Novak, Moore & Leidy (2011). Nestedness patterns and the dual nature of community disassembly in California streams: a multivariate permutation-based approach. *Global Change Biology*. 17: 3714-3723.

Bolnick, Amarasekare, Araújo, Bürger, Levine, Novak, Schreiber, Urban & Vasseur (2011). Why intraspecific trait variation matters in community ecology. *Trends in Ecology & Evolution* 26(4): 183-192.

Doak, Estes, Halpern, Jacob, Lindberg, Lovvorn, Monson, Tinker, Williams, Wootton, Carroll, Emmerson, Micheli & Novak (2008). Understanding and predicting ecological dynamics: are major surprises inevitable? *Ecology* 89 (4): 952-961 (*Concepts & Synthesis*).

Research grants:

NSF/NOAA Comparative Analysis of Marine Ecosystem Organization, *2010, $590,000.*
PIs: Carr, Estes, Tinker, Levin, Caselle *(ghostwriter; UCSC prohibits postdoctoral researchers from being PIs on major funding proposals).*

NSF Doctoral Dissertation Improvement Grant, *2006, $12,000*.

Environmental Protection Agency STAR Fellowship, *2005, $136,000*.

Synergistic activities:

Symposium Organizer, Ecological Society of America, *2011.*
The Ecological Consequences of Individual Variation.
Co-organizer: Dan Bolnick.

National Institute for Mathematical and Biological Synthesis working group, *2009-11.*
Population and community consequences of intraspecific niche variation.
Organizers: Dan Bolnick, Volker Rudolf & Kevin McCann.

National Center for Ecological Analysis and Synthesis working group, *2006-9.*
Conservation planning for ecosystem functioning: Testing predications of ecological effectiveness for marine predators.
Organizers: Dan Doak, Jim Estes, Tim Wootton & Terrie Williams.

Reviewer: *The American Naturalist, Ecological Modelling, Ecology, Ecology Letters, Journal of Animal Ecology, Journal of Molluscan Studies, Oecologia, Oikos, Proceedings of the Royal Society B.*

Invited seminars (last 2 years):

University of Cincinnati (*Dept. of Biology*), Oregon State University (*Dept. of Zoology*), Queen's University, Belfast, Ireland (*Dept. of Biology*), University of Utah (*Dept. of Biology*), National Center for Ecological Analysis and Synthesis, California Polytechnic University, San Luis Obispo (*Dept. of Biology*).

Collaborators and other affiliations:

Recent collaborators:
Dan Bolnick, *University of Texas, Austin*; Don DeAngelis, *USGS*; Dan Doak, *University of Wyoming*; Mark Emmerson, *Queen's University,* Paulo Guimarães Jr., *Universidade Estadual de Campinas, Brazil*; Robert Leidy, *EPA*; Justin Yeakel, *University of California at Santa Cruz*.

Ph.D. committee:
Priyanga Amarasekare, *University of California at Los Angeles;* Greg Dwyer, *University of Chicago;* Michael Foote, *University of Chicago;* Cathy A. Pfister, *University of Chicago;* David R. Schiel, *University of Christchurch, New Zealand;* J. Timothy Wootton, *University of Chicago* (Graduate advisor)

Postdoctoral sponsors:
Mark Carr, *University of California at Santa Cruz;* Jim Estes*, University of California at Santa Cruz;* Jonathan W. Moore, *Simon Fraser, Canada* (previously *UCSC*); M. Tim Tinker, *U.S. Geological Survey & University of California at Santa Cruz*