What we're in for:
The bibliometrics of SIO dissertations

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Introduction

At the end of my second quarter as a SIO Ph.D. student, I realized I still had no concept of what a dissertation actually is. How do the demands of a dissertation compare to what I have accomplished in the past? Is it conceivable? Am I capable? How long do dissertations tend to be? How many chapters are they supposed to have? How big are these chapters? How are they related? *Are* they related? How many pages, words, figures, or references are we talking about here? What the hell have I gotten myself into?

All this ignorance smacked of poor planning, naiveté, and aimlessness. Here I am, committed to a 6-year (or more) program, and I'm not even sure what that commitment really entails. Like all first years, I have already felt the pressure to develop thesis-worthy research questions even while bombarded with course requirements. But how can I know what is thesis-worthy or not, if I don't know what a thesis is first? If this dissertation is supposed to be the launching pad into the world of professional science, a portfolio of my scientific capacities, a showcase of my merit, and a trophy of my late twenties and early thirties, why don't I know more about what it entails?

These questions were basic, and that made my ignorance seem all the more egregious. But I was even more startled by the realization that no one was going to feed me the answer. There was no orientation program on this, no brown bag seminar to attend, no handbook handed down from upper-classmen. Unless I took action, I would have to discover *along the way* what it is that I'm on my way towards. Surely this would be inefficient, fraught, and needless. If I wanted to get a handle on what I'm in for, it would be up to me to do it. This small report is the result of that resolve.

What is in store for us students? I set out to answer this question using two methods: (1) review recent dissertations, and (2) attend some dissertation defenses. This report is concerned primarily with the first: I surveyed 20 dissertations from the last 8 years (2004-2012). In an effort to keep the results as representative as possible of what is expected of current students, ten of these dissertations were more recent than 2009 (and therefore were only available online; Table 1).

The idea is that a metric portrayal of the dissertation document can serve as some sort of loose proxy for the science that it entails. Now, I am fully aware that word counts and figure tallies say very little about the effort that goes into a 5- or 6-year dissertation. Nor does a dissertation fully represent all the painstaking work that a student does within that timeframe. So much does not get incorporated into the final product, many dead-ends are encountered, and a lot of heart and soul goes into projects that will not receive any page time in the final draft. However, the actual writing of a dissertation is still an important and daunting component of the Ph.D. experience, and it will serve as the primary source of your qualifications as a "Doctor." Knowing what is in store, at least for the writing component of a thesis, should empower students to approach its less tractable dimensions with more confidence.

Methods

I conducted these reviews over several afternoons in March 2012. Dissertations were chosen quasi-randomly (Table 1): for the printed dissertations, I scanned the shelves in the SIO library (2^{nd} floor) for any that were more recent than 2004 and pulled the first 9 that I encountered. Electronic dissertations were chosen with more discretion, out of a desire to keep this review most relevant to me and to my closest peers. I therefore preferentially opted for topics in cetology, biological oceanography, or marine biology, but made sure to prioritize publication date as the primary selection criterion.

For each dissertation, I recorded basic metrics and surveyed the thesis' basic layout, mainly by closely reading the narrative outlines in the preface and introduction. The following information was recorded for each dissertation: Curricular group, author, year of completion, thesis title, total number of pages, total number of references (for electronic versions only), number of chapters, length in pages of each chapter, length of front matter materials, number of figures and tables, committee members, the dedication, narrative outline of the thesis (often copied from the Preface), and finally any unusual formatting or organizational decisions. I was particularly interested in the level of unity and relatedness between chapters (e.g., is this dissertation a monograph or a collection of discrete papers?).

Methodological minutiae are addressed in Appendix 1.

Results: Your Dissertation

Based on the results of my bibliometric review, here's what you, the student, can expect your dissertation to entail. Again: this will not say much about the *science* that goes into all the words and figures tallied here, but perhaps you can use these numbers as an interesting proxy for what is in store.

The bound copy of your dissertation will be printed single-sided, double-spaced, and boast broad margins. Type will be 12 pt. TNR, Courier, or the like.

Length

In its final format, your dissertation will total around 192±19 pages in length (95% confidence intervals; this format will be used throughout). This may seem like a lot, but keep in mind that about 20±2 pages will be occupied with "front matter" (copyright information, acknowledgments, dedication pages, tables of content, title pages, etc.), and that many more pages will be taken up with references (~13p.) and figures and tables (~60p.). All this extraneous material will occupy about 56% of your total pages, leaving you with about 84 pages of scientific text.

This may still sound like a lot, but also keep in mind that your pages will be egregiously double-spaced with generous margins. Single-spaced, your dissertation will have 42 pages of scientific writing. But word counts may still be more illuminating: your dissertation will be a total of ~36,428± 6,296 words, although that number obviously ranges widely. To put this in perspective, many mid-length nonfiction (~250p.) natural history books contain about 75,000–100,000 words. Short, 150p. books are somewhere around 50,000-60,000 words.

Contents

Your dissertation will consist of the following content:

~ Front Matter:
- Title page
- Committee approval page
- Dedication page(s)
- List of Abbreviations
- Table of Contents
- List of Figures
- List of Tables
- Preface
- Vita, Publications, and Fields of Study,
- Abstract

~ (*Optional:* Introduction)
~ Chapters (with references at the end of each chapter)
~ (*Optional:* Conclusion)

Front Matter

Your dissertation will have about 20±2 pages of "front matter", the conventional formalities of all such official school reports. Some of this matter is tedious (e.g., tables of contents, title pages, committee signature pages), but other sections are probably fun to write (e.g., the acknowledgments). In your acknowledgements, you will be sure to lavish thanks upon your adviser.

Your dedication page will of course be entirely personalized, as succinct or elaborate as you desire. It might include a quote that somehow represents your Ph.D. experience, and maybe even a photo (1 of the 20 dissertations I reviewed had a photograph on its dedication page; black-and-white, of friends watching the sunset at the Torrey Pines glider port; Stukel 2011). Another dedication had a two-page quote from Pablo Naruda's poem, "Oda al Mar" (Vilchis 2010). One dissertation did not have a dedication page, but her acknowledgments were particularly extensive (McKenna 2011). Examples of dedications from my review can be found in Appendix 2; they are sweet and fun to read.

Chapters

Your dissertation will consist of 4, maybe 5 chapters. 65% of you will also choose to include a short (~10 p.) introductory chapter that introduces your field site, study region, or the taxon you are focusing on throughout the chapters that follow. Only 30% of you will include a conclusion at the end of your dissertation.

Here is the typical layout of each chapter:

Title
A. Abstract
B. Introduction
(*Optional:* Examination of existing data)
C. Materials and Methods
D. Results
E. Discussion
E. Conclusion/Summary
G. Acknowledgements (regarding research)
H. References
I. Appendices

On average, each of your chapters will be ~46 ±7 pages in length double-spaced, much of which will be tables or figures. In terms of text, your chapters will be ~13,614± 2,037 words (max=20,467; min=9,312).

Your chapters might be very different lengths relative to each other. The average coefficient of variation (CV) of chapter lengths within a dissertation is 32.8%, while the maximum CV from a sampled dissertation was 92% (in which the shortest chapter was 12 p. and the longest was 91 p.; Drazen 2006).

To put this in perspective, a typical 15-page NSF proposal (single-spaced), which many of first-years have experience writing, is about 8,500 words. Given that these proposals consist mainly of Literature Review, Methods, and Hypotheses, rounding them off with Results and Discussion at a similar level of detail (and doing the science required to populate those sections) would be enough to yield a single dissertation chapter.

Many of these chapters, if not all, will be manuscripts of articles that are published, submitted, or in preparation for submission to major peer-reviewed journals. If so, you will mention this in your thesis' preface (*more below)* and in the concluding remarks of each chapter. One or two of your chapters may be co-authored by other scientists, but you will be the first author on all of the chapters.

Unity of chapters

The preface of a dissertation (or, occasionally, the Introduction) is where the student spins a coherent story out of her chapters, linking them in a kind of narrative table of contents. Perhaps the hardest question to get at is just how focused a dissertation has to be. This changes with the evolving fashions of professional science, with the institution's expectations, the advisor's standards, the nature of the student's interests, and the student's career goals. The overall trend in the last two decades seems to have been a move from a single monograph broken into chapters to a collection of multiple papers, each comprising a single chapter, linked loosely by some overarching theme. "Just staple 4 or 5 papers together." But how different and disconnected can these papers actually be? How "forced" or contrived can that theme be before it is *too* contrived?

The dissertations I reviewed were more coherent and focused than I had expected, but the range of "coherency" was still vast. In Appendix 3, I have provided the chapter outlines and narrative rationale, in the author's words, from 9 of the sampled dissertations. Hopefully these synopses provide a picture of the range of structure these dissertations have: some are collections of fairly disparate papers connected loosely by some over-arching idea or area of study, while others are tightly knit hierarchical analyses of a very specific topic.

Figures & Tables

Although this varies greatly according to your topic, your dissertation will have about 51±14 color figures (max=161!!!; min=15) and about 10± 2 tables (max=16; min=3), or ~13 figures and ~3 tables per chapter. Each figure or table will be presented alone on a whole page, meaning about 51 of your total page count will be occupied. (This, to me, is one of the most daunting aspects of the whole endeavor. *Fifty* carefully designed figures – yikes!!!)

References

Your dissertation will have ~182 references ±37. These references will probably be reported at the end of each chapter, but some of you (~10%) will opt to put them all in the back in a single section. These references will take up a total of about 14 pages of your thesis.

Extremes

It might be illuminating to consider the dissertations at the extremes of the sampled set, particularly in terms of length. Length was ranked according to approximate word count of the scientific text (i.e., not including front matter or references) in the thesis. Be cautioned that this choice of ranking method might be misleading; note that the "shortest" dissertation had more figures and references than the "longest". Clearly, the measuring stick you use matters a great deal.

The Longest:

Cook (2011) of Marine Biology, on rocky reef fish connectivity. 253 pages, approximately 50,300 words of scientific text, 5 chapters, chapter length CV 5.5% (very uniform), 25 figures, 10 tables, and 200 references. Of note is the fact that Cook's thesis was only slightly longer than several others (9 were over 200 p., 6 of which were more than 230 p.). Others had more chapters than Cook's: Janousek (2009) was the only thesis sampled with 7 chapters, and two had 6 chapters (McKenna 2011; Giddens 2005).

The Shortest:

Of the 10 dissertations more recent than 2009, the shortest was Vilchis (2010), a Biological Oceanography student from Mexico, whose thesis was a retrospective analysis of ecosystem responses to climate oscillations in the 1970's. 182 pages, approximately 20,660 words of scientific text, 2 chapters, chapter length CV of 15.4%, 33 figures, 8 tables, and 249 references (the 2nd highest count of any dissertation sampled!).

Interestingly, if ranking according to total pages, Vilchis (2010) is not the shortest: 4 of the 9 had lower page counts, the smallest being 126 p. (Carter 2011). However, these tended to have much fewer references, figures, and tables, meaning total scientific text was greater than that found in Vilchis (2010).

Concluding Remarks

I find it very helpful to know what the final product of a project is going to look like before I set to work. Perhaps other students feel the same, and perhaps this report is helpful in that respect. We're all trying to wrap our heads around how our efforts over the next several years will finally be distilled. If these metrics represent the average expectations for a thesis, then maybe this report will help us scale and mold our research questions into something feasible. By knowing minimum and basic standards, we are better able to brace ourselves, plan ahead, set a sustainable pace, and maximize the quality of what we deliver.

Of course, there are still many components to the ordeal of the thesis that I have not addressed at all, nor do I have any data or hearsay with which to do so: e.g., selecting a committee (the interviews, the paperwork, etc.), qualifying (I have no idea what this means), going through drafts with your committee, applying to defend, what happens after defending, etc. Much remains to be learned, but perhaps these concerns will not be too painful to deal with as they come.

As a fun exercise, I would advise fellow students to look up their advisor's thesis, and also to ask their advisors for copies of dissertations from their former students. This will give you a good idea, based on their own Ph.D. experience and their work with former students, of what they might be expecting from you. This can be surprisingly comforting. For instance, my advisor, who graduated from SIO in 1982, misspelled "Abstract" in his Table of Contents, and had a typo in the first sentence of his introduction! These are superficial and meaningless mistakes, but there's something humanizing about that. (That said, he has also served on the committees for the most impressive and lengthy dissertations I reviewed for this report. Yikes!)

If students are looking for more on what the actual writing and formatting of a thesis entails, I invite them to skim through the UCSD dissertation preparation manual, available online. Perhaps the most rewarding and least time-intensive way of learning more about the dissertation experience is attending some doctoral defenses. I encourage all to do so as often as they can. Lastly, I would invite my peers to get a head start in becoming familiar with word processing programs that will make the thesis writing experience less onerous in the long road, such as *Sweave*, a program that allows writers to embed R code into Latex documents, making it easier and less scattered to write while conducting analyses simultaneously.

Table 1. The 20 dissertations used in this survey. An asterisk (*) aside the year indicates that this dissertation was accessed electronically.

Curricular Group	Author	Year	Thesis Title
BO	Christopher N. Janousek	2005	Functional Diversity and Composition of Microalgae and Photosynthetic Bacteria in Marine Wetlands: Spatial Variation, Succession, and Influence on Productivity
BO	Megan McKenna	2011*	"Blue whale response to underwater noise from commercial ships."
BO	Andrew J. Lucas	2009*	Aspects of the physical control of phytoplankton dynamics over the Southern California Bight continental shelf
BO	Michael Raymond Stukel	2011*	Biological Control of Vertical Carbon Flux in the California Current and Equatorial Pacific
BO	L. Ignacio Vilchis	2010*	A retrospective study of ecosystem effects of the 1976/77 regime shift in the eastern Pacific warm pool
BO	E. Elizabeth Henderson	2010*	Cetaceans in the Southern California Bight: Behavioral, Acoustical and Spatio-temporal Modeling
BO	Sarah Glaser	2009*	Foraging ecology of North Pacific albacore in the California Current System.
BO	Lisa Marie Munger	2007*	North Pacific Right Whale Calling Behavior and Habitat Characterization in the Southeastern Bering Sea
MB	Jeanine Marie Donley	2004	Mechanics of steady swimming and contractile properties of muscle in elasmobranch fishes
MB	Grace Lim	2004	Bugula (Bryozoa) and their bacterial symbionts: a study in symbiosis, molecular phylogenetics and secondary metabolism
MB	Katie Lynn Cramer	2011*	Historical change in coral reef communities in Caribbean Panama
MB	Geoffrey Scott Cook	2011*	Rocky Reef Fish Connectivity: Patterns, Processes, and Population Dynamics
PO	David Drazen	2006	Laboratory Studies of Nonlinear and Breaking Surface Waves
PO	Luc Rainville	2004	Propagation of the Internal Tide from the Hawaiian Ridge
PO	Robert Todd	2011*	Upper ocean processes observed by underwater gliders in the California Current System
GP	Julie Ann Bowles	2005	Paleointensity of Earth's magnetic field, with applications to the study of mid-ocean ridge accretionary processes
GP	Eric M. Giddens	2005	Geoacoustic Inversions Using Sound from Light Aircraft
AOS	Scott L. Nooner	2005	Gravity Changes associated with underground injection of CO2 at the Sleipner storage reservoir in the North Sea, and other marine geodetic studies,
CO	Brendan Rae Carter	2011*	Methods for Hydrographic Data Collection and Use Applied to Infer Biogeochemistry in the Southern Ocean
MNP	Joel Sandler	2005	Anticancer Compounds from Marine Invertebrates

APPENDIX 1: Methodological Minutiae

Of the 20 dissertations reviewed, 8 were from Biological Oceanography (BO), 4 were from Marine Biology (MB), 3 were from Physical Oceanography (PO), 2 were from Geophysics (GP), and the remaining 3 were from Chemical Oceanography (CO), Marine Natural Products (MNP), and Atmosphere & Ocean Climate (AOC). I avoided dissertations that were obviously written by candidates for whom English was their second language, in case standards were slightly adjusted for them.

Most of the bibliometrics reported above were calculated using a meager sample size of 20 dissertations. However, some metrics, including those regarding references, front matter, and word counts per page, were calculated using only the 11 dissertations accessed electronically, all of which were more recent than 2009. For the sake of reducing textual clutter, these sample sizes were not stipulated with every metric above, so let this suffice.

There were two dissertations whose chapters consisted of photocopies of published articles (Bowles 2005, Donley 2004). Published articles contain much smaller type in compactly arranged columns, and as such contain much more text per page than a normal dissertation page. To allow these dissertations to contribute to the bibliometric analyses I conducted, I had to account for this formatting discrepancy. I did so with a crude transformation: double the page counts for chapters consisting of photocopied journal articles.

In almost every dissertation I looked at, each figure or table was given an entire page to itself. Therefore, by knowing the total number of figures and tables in the thesis (counted up in the contents section of the front matter), I could calculate the total number of pages in the dissertation that figures and tables occupied. In the rare case that the author formatted such that multiple figures or tables occupied a page (Henderson 2010, Munger 2007, Carter 2011), I made a crude estimate of the average number of figures he or she would fit on a page, then adjust this "occupied" page count accordingly.

Reference metrics were only obtained for the 11 electronically accessed dissertations, because the number of references cited was provided by the online catalog. I did not check to see if references re-used in multiple chapters were counted only once. Here I assume they were counted only once.

The number of pages that references occupied in a dissertation were calculated in a sidelong matter: I took the total number of references a dissertation contained and divided this by the average number of references per page a thesis typically contained. This metric was determined by taking 5 random samples from 3 randomly chosen dissertations. A sample consisted of counting the number of references listed on a page. The mean of the 5 samples for each paper were then taken, and the three means were then averaged to yield an average reference density of 13.8 references per page.

Words per page were calculated in a similar manner: The words on 5 randomly chosen pages within a dissertation were counted then averaged. This was done for 3 randomly chosen dissertations, and the three means were averaged to yield a grand words/page metric of 291.

APPENDIX 2: Examples of Dedications

This dissertation is dedicated to my parents. They have given more than I could ever repay.
(Barlow 1982)
(This thesis was not one of the 20 sampled, but he's my advisor, so I looked him up.)

"There's two possible outcomes: if the result confirms the hypothesis, then you've made a discovery. If the result is contrary to the hypothesis, then you've made a discovery."
~ Enrico Fermi *(Nooner 2005)*

This dissertation is dedicated to Fozzy, who has guarded the office for many years, and to Moira, Brendan, and Jenny, who are my friends. *(Stukel 2005)*

For his passion to understand the ocean and the creatures who swim within, this dissertation is dedicated to John Lagrange and the memory of his wife, Linda. Without Mr. Lagrange, I might never have decided to study albacore, a powerful and beautiful fish that has taught me an incredible amount. Thank you, John, for your insight and your guidance, for the support of the American Fisherman's Research Foundation and the commercial albacore industry, and for prioritizing the role of scientific inquiry in management while reminding us of our limitations. This study would not have been possible without you.
(Glaser 2009)

For whatever we lose / (like a you or a me) / It's always our self / We find in the sea.
~ e.e. cummings *(Munger 2007)*

For: My parents who taught me to learn (and how to learn), My brother who gave me my love of worlds (especially our own), My friends (who are great), And the hope that insight and conscience can inform action. *(Carter 2011)*

To Mom and Dad, who gave me my wings, and to Rebecca, who taught me to fly.
(Giddens 2005, who did aerial surveys in a small plane for his research)

To Mom and Dad, for giving me the imagination to dream the impossible and the means of attaining it. *(Sandler 2005)*

To Mom and Dad. Thanks for everything. *(Cook 2011)*

Other part of dedication: / I am caught by the undertow
Within the heart of the sea / In all of the oceans beauty
It was only by your love / That I ever felt free
Force is not in need / To drag me any deeper
And in my hand / I hold my heart
As I question to take it off my sleeve / Heaven has no greater beauty
Than this twisted sea
~ Joseph Stotz (*Henderson 2010)*

APPENDIX 3: Thinking about "Focus": Dissertation outlines

What follows are the synopses of thesis organization and the progression of topics within 11 of the dissertations sampled. Each outline was copied directly out of the dissertation's Preface, in which the author laid out the rationale behind the structure and organization of the chapters with each other.

Carter 2011
"Methods for Hydrographic Data Collection and Use Applied to Infer Biogeochemistry in the Southern Ocean"

Committee:
Andrew Dickson, Chair
Ralph Keeling,
Jeffrey Severinghaus
Lynne Talley,
William Trogler

Introduction

Chapter 1: An automated system for spectrophotometric seawater pH measurements

Chapter 2: A model for biogeochemical cycling in deep mixed layer waters entrained into Subantarctic Mode and Antarctic Intermediate Waters

Chapter 3: Inferring changes in biogeochemical processes from hydrographic property measurements in the Pacific sector of the Southern Ocean

(Summary is too long to include. But the structure is laid out in the Intro.)

Cook 2011
"Rocky Reef Fish Connectivity: Patterns, Processes, and Population Dynamics"

Committee:
Lisa A. Levin, Chair
David M. Checkley
Paul K. Dayton R
obert T. Guza
David A. Holway
P. Ed Parnell

Chapter I. Introduction
Chapter II. Influence of protected status and habitat structure on the distribution and abundance of a temperate rocky reef damselfish, *Hypsypops rubicundus*
Chapter III. Changes in otolith microchemistry over a protracted spawning season influence assignment of natal origin
Chapter IV. High-frequency shifts in connectivity patterns within an open-coast marine protected area network: is the whole greater than the sum of its parts?
Chapter V. Demographic connectivity deconstructed: an exploration of the demographic consequences of larval dispersal
Chapter VI. Quantifying connectivity in marine metapopulations
Chapter VII. Conclusions

To avoid the "shifting baselines" syndrome (Pauly 1995), and enable an assessment of connectivity patterns in a "pristine" setting I selected garibaldi, a species that has been protected for approximately 30 years (Appendix 1.1, Chapter 2). Hundreds of exploratory dives were completed to identify the largest populations of garibaldi in San Diego County (Chapter 2). After identifying the possible source populations, it was necessary to test the spatial and temporal stability of otolith trace elemental fingerprints to validate the utility of this method for quantifying population connectivity via larval dispersal (Chapter 3). Using high resolution sampling over the three month garibaldi spawning season I re-created larval dispersal trajectories, and from these data developed estimates of larval dispersal distance, directionality, and magnitude (Chapter 4). From these connectivity data I quantified local retention, and regional settlement within the MPA network located along the open coastline of San Diego County (Chapter 4). Coupling these connectivity data with stage-based matrix population models I tested the relative contribution of vital rates and inter-reef connectivity on reef-level and metapopulation growth rates (Chapter 5). Using simulation modeling I explored the role of connectivity in metapopulation dynamics, providing insights into the possible roles of connectivity in managing natural resources (Chapter 5). Building upon these data generated in earlier chapters I applied qualitative and quantitative food-web metrics to realized connectivity data and using node deletion experiments created a method of quantifying the value of individual reefs to the six reef metapopulation (Chapter 6).

Cramer 2011
"Historical change in coral reef communities in Caribbean Panama"

Committee:
Jeremy Jackson, Chair
Christopher Charles
James Leichter
Richard Norris
Naomi Oreskes

CHAPTER 1: Geography, human occupation, and environmental change in western and central Caribbean Panama

CHAPTER 2: Historical change in coral communities in Caribbean Panama

CHAPTER 3: Historical change in coral reef bivalve and gastropod communities in Caribbean Panama

CHAPTER 4: Ecological change on Caribbean coral reefs before coral disease and bleaching

Glaser 2009
"Foraging ecology of North Pacific albacore in the California Current System."

Committee:
David M. Checkley, Jr., Chair
Josh Kohn
Mark D. Ohman
George Sugihara
George Watters
Brad Werner

Chapter 1. Introduction

Chapter 2. Quantifying interdecadal variability in diet habits, prey energetics, and consumption rates of North Pacific albacore in the California Current System
The diet data presented in this dissertation are used to investigate albacore foraging ecology in three complimentary ways. In Chapter 2, I present newly collected diet data in the context of four historical studies to investigate the hypothesis that albacore diet has changed over time to reflect an increase in sardine in the environment. I reanalyze historical diet studies, originally framed by traditional metrics of diet habits (numeric abundance and frequency of occurrence), using the more contemporary approach of bioenergetics. When analyzed according to energetic contribution, the diet habits of albacore in the CCS are more narrow than previously described. The majority of albacore diet is comprised of saury and anchovy, and recently hake (Merluccius *productus)* have become important. Sardine never have been found in significant amounts in albacore diet, contrary to expectations. I argue that, although albacore are opportunistic predators, thermal optimization confines them to certain water masses even in the face of abundant prey elsewhere, and I suggest that albacore do not occupy the same waters as sardine.

Chapter 3. The foraging ecology of North Pacific albacore in the California Current System
Chapter 3 describes the foraging ecology of albacore through patterns of variability in diet habits at medium spatial and temporal scales, and small scales of taxonomic resolution. I present the detailed results of gut content analysis of 371 albacore collected in 2005 and 2006, making regional comparisons of prey diversity and quantifying the daily consumption rates of albacore. First, I describe species-level patterns of albacore diet habits in the CCS and discuss prey ecology. Second, I compare individuals and aggregations of foraging albacore to describe differences in energy content, biomass consumed, and prey aggregations. Third, I compare prey consumed in three different regions of the CCS (north, central, and south). Finally, I classify albacore foraging strategy using graphical means of comparing individual prey diversity to population prey diversity. Based on the results of Chapter 2, I hypothesize and demonstrate that albacore are not true generalists; rather, they display foraging strategies more closely approximating transitory specialists or a mixed-feeding strategy based on specialization on one or two prey with a broad supplement of more rare prey.

Chapter 4. Do albacore exert top-down pressure on Northern anchovy? Estimating mortality of juvenile anchovy as a result of predation by North Pacific

albacore.

Chapter 4 investigates the predation impact of albacore on their most important prey, Northern anchovy. First, I estimate the abundance of juvenile North Pacific albacore in the CCS from 1966-2005. Second, I quantify the annual consumption of the central stock of Northern anchovy by albacore. Finally, given the large population of albacore (ISC 2006) and the significant fraction of their diet comprised by anchovy (Chapters 2 and 3), I hypothesize that albacore exert top-down pressure on anchovy. Borrowing generalizations gleaned from experiments in intertidal zones, I expect an inverse relationship between albacore abundance and anchovy abundance. I demonstrate that albacore consume between 1 – 5% of anchovy recruitment biomass annually. Furthermore, changes in albacore population abundance in the southern CCS are negatively correlated with changes in anchovy recruitment biomass the following year, suggesting the potential for top-down effects on anchovy.

Chapter 5. Conclusion

Chapter 5 presents concluding remarks. This dissertation is the first to quantify interdecadal variability in diet habits of an important marine predator, and the findings have implications for marine ecosystems. Albacore diet has been surprisingly stable despite significant changes in the marine communities in the CCS. Contrary to expectations, albacore do not consume Pacific sardine, and their niche width is more narrow than previously assumed. Northern anchovy are a critical prey species for albacore, and models containing albacore or anchovy could be improved by focusing on this key interaction. Although conventional wisdom classifies albacore as generalists, their mixed-approach to foraging means they may be more sensitive to dramatic changes in important prey species, especially Northern anchovy. Finally, the role of albacore in the CCS, while transitory, appears to be sufficient to impact at least one population of prey.

Hendersen 2010
"Cetaceans in the Southern California Bight: Behavioral, Acoustical and Spatio-temporal Modeling"

Committee:
John A. Hildebrand, Chair
Jay P. Barlow
Phil Hastings
William Hodgkiss
Jim J. Moore

Ch 1. Intro

Chapter 2. The Behavioral Context of Common Dolphin (Delphinus sp.) V ocalizations..
Chapter two, entitled "The Behavioral Context of Common Dolphin (Delphinus sp.) Vocalizations", describes the results for common dolphins, and includes an analysis of the relationship between surface behavior, group size, group spacing, and rates of vocalizations. The dominant behavior recorded for common dolphins was traveling, as groups traveled offshore in the afternoon and onshore in the morning. The highest number of clicks, pulsed calls, and complex whistles were produced during fast travel, while during foraging there were few pulsed calls and whistles produced, and the whistles were simple with narrow bandwidths and few harmonics. In addition, while little daytime foraging was observed, night-time vocalization patterns strongly suggest that common dolphins were foraging nocturnally in offshore waters.

Ch 3. Classification of Behavior Using Vocalizations of Pacific White- Sided Dolphins (Lagenorhynchus *obliquidens)*
Chapter three, "Classification of Behavior Using Vocalizations of Pacific White- Sided Dolphins", examines the behavioral patterns and vocalizations of the two populations of Pacific white-sided dolphins, and demonstrates the strong differences between them. "Type A" click groups were observed slow traveling and milling during the day, while "Type B" click groups spent much of their time foraging and traveling. In addition, call patterns varied between the two groups, with more clicking during milling and foraging for "Type A" click groups and more clicking during mixed forage and slow travel for "Type B" click groups. Finally, call features differed significantly across behavioral categories, and classification models using random forest decision trees showed strong potential for using vocalizations to predict behavior.

Ch 4. The Role of Marine Mammals as Top Predators: An Analysis of Marine Mammal Occurrence and Oceanographic Patterns in the Southern California Bight
My second goal was to examine patterns of marine mammal occurrence and distribution related to oceanographic features across different temporal and spatial scales. Chapter four, "The Role of Marine Mammals as Top Predators: A Multi-Step Analysis of Marine Mammal Occurrence Patterns in the Southern California Bight", examines the occurrence patterns of all marine mammals in the SCB across three years, using a point-sampling method. The Floating Instrument Platform (R/P FLIP) was deployed off San Clemente Island in the fall

of three consecutive years. All marine mammals were recorded, along with multiple oceanographic features. Marine mammal sightings were then correlated with biotic and abiotic parameters, including SST, thermocline depth, chlorophyll concentrations, zooplankton abundances and estimated fish biomass, to look for occurrence patterns across time. 2006 was the most speciose year, with multiple dolphin and whale species present in high numbers, along with warm SST's and a possible front between water masses located nearby. Fin whale (Balaenoptera *physalus)* and northern elephant seal (Mirounga *angustirostris)* sightings peaked in 2007, a cooler year with more stratification and higher chlorophyll concentrations. 2008 was also warm, with a deep thermocline and deep chlorophyll maximum depth, but had the fewest sightings of dolphins and whales, although high numbers of California sea lions (Zalophus *californianus)* were recorded. Zooplankton abundances and fish biomass were also estimated in 2008, with non- eucalanoid copepods and siphonophores dominating the zooplankton, and northern anchovy (Engraulis *mordax)* and jack mackerel (Trachurus *symetricus)* presumed to dominate the fish biomass aggregated around FLIP.

Ch 5. Effects of Sea Surface Temperature Variation on the Distribution of Small Cetaceans in the Southern California Bight: Implications for Climate Change

Finally, in chapter five, "Effects of Sea Surface Temperature Variation on the Distribution of Small Cetaceans in the Southern California Bight: Implications for Climate Change", I modeled the distribution patterns of eight dolphin species in the SCB across temperature fluctuations on three different temporal scales using a 30-year dataset of observations. Changes in distribution were examined across seasonal temperature fluctuations on an annual scale, El Niño/Southern Oscillations (ENSO) on a 2-7 year time scale, and Pacific Decadal Oscillations (PDO) on a decadal time scale. Model results varied among species, but each included at least one SST variable and one depth variable, indicating changes in distributions correlated with SST fluctuations. Implications of the results are considered in light of changing ocean temperatures and the potential impact on the species investigated here.

Each of the following chapters is intended to stand alone as a publishable unit, and the reader may encounter some redundancy in the introduction and methods for each chapter. Chapter two, entitled "The Behavioral Context of Common Dolphin (Delphinus sp.) Vocalizations", has been submitted to Marine Mammal Science and is presented as part of this dissertation with acknowledgement to the co-authors in the study.

Lucas 2009
"Aspects of the physical control of phytoplankton dynamics over the Southern California Bight continental shelf"

Committee:
Peter J. S. Franks (Chair)
John L. Largier
James Leichter
Robert Pinkel,
William Propp
Clinton Winant

All chapters are in part submitted for publication.

All chapters are based on data collected with ISPX experiment.

Chapter 2 The hose and the sprinkler: Complementary roles of horizontal and vertical internal wave-forced nitrate flux over a narrow continental shelf
In Chapter 2, I present an analysis of the nitrate flux to the inner shelf euphotic zone mediated by internal waves of tidal and higher frequencies. I show that the vertically integrated energy and nitrate fluxes are onshore, dictating that sinks exist over the inner shelf for both quan- tities. Energy is lost by mixing, and nitrate is taken up by the phytoplankton, leading to the persistent elevation of new and total productivity over the inner shelf. Estimates of nitrate flux forced by the tide compare well with our estimates of phytoplanktonic nitrate uptake based on laboratory experiments. We explicitly consider the separation between the vertical flux of nitrate, typically considered the important flux pathway, and the horizontal flux of nitrate due to the internal tide, which has not been previously examined. The enhanced importance of nitrate flux to the surface waters inshore, reflected in the surface new productivity gradients, implies that the internal tide-driven horizontal flux of nitrate is being redistributed vertically. Simple estimates of mixing based on the loss of kinetic energy across the ADCP array show that a portion of the horizontal flux is mixed upwards. The horizontal flux is essentially along-isopycnal, which, at the scale of the shelf, implies a vertical redistribution of nitrate due to the persistent onshore shoal- ing of the isopycnals. It appears that the onshore transport and vertical redistribution of nitrate by internal wave processes maintains the gradients in productivity observed over the SSCB shelf (Eppley 1992).

Ch 3. The green ribbon: physical control of phytoplankton productivity and community structure over a narrow continental shelf
In Chapter 3, I show that the gradients in total and new productivity across the shelf are concurrent with changes in the composition of the phytoplankton community towards taxa typical of areas with moderately high levels of nitrate input. In both the surface waters and at the subsurface chlorophyll maximum, the vital rates and character of the phytoplankton community are quite different over the relatively short spatial scale of the shelf (~10 km). The internal wave mediated nitrate flux discussed in Chapter 2 appears in general to support these gradients. However, physical context of these internal wave processes can lead to large changes in the potential for nitrate flux. The local alongshore wind is well correlated with the vertical shear in subinertial alongshore velocity that balances the

persistent tilt in the pycnocline and nitracline. This wind is too weak to cause large across-shelf transports—particularly given the strong onshore sea breeze—and therefore does not support the observed biological gradients alone. Instead, it acts to set up the isopycnals, thereby enhancing the biological impact of the along-isopycnal internal wave-mediated nitrate flux. There are also large changes in the depth of the nitracline at the shelf break which are not related to local forcing. I show that this remotely-forced variability can drastically alter the nitrate climate over the shelf. For example, a re-analysis of historical records indicates that during prolonged periods of anomalously warm temperatures (e.g. El Niño events), the depression of the nitracline at the shelf edge shuts of the supply of nitrate to shelf and leads to exceptionally low standing stocks of phytoplankton.

The integrated view presented in Chapter 3 identifies the physical mechanisms responsible for the productivity and community composition of the SSCB continental shelf phytoplankton, an open issue since the 1980s (Eppley 1992). Moreover, I demon- strate that the subtle interaction across different scales of physical variability combine to establish the biological character of the phytoplankton over the SSCB shelf.

Ch 4. The semidiurnal baroclinic variability over the Southern California Bight in- nershelf

In Chapter 4, I address the nature of the semidiurnal variability over the inner shelf. I show that, contrary to previous interpretations, the semidiurnal variability in waters < 20 m appears not to result from a propagating or standing low mode internal wave, based on the sense of rotation of the baroclinic semidiurnal currents. Instead, in these shallow waters, it appears to be driven by the barotropic tide directly. I assess simplified alongshore and across-shore momentum balances, and show the importance of rotation, friction, and the cross-shore and along-shore gradients in sea level. The baroclinic semidiurnal variability behaves in a manner similar to a recent theoretical model of tidal circulation in an estuary (Winant 2007, 2008), where the cross-shelf flow is driven by an imbalance between the forcing of the cross-shelf sea level gradient and the Coriolis force associated with the vertically sheared alongshore transport. The ob- servations do not exactly fit the theory as developed here, and further field and model investigation is required to conclusively assess the validity of this hypothesis. However, if validated, it would be a novel description of the internal tide in shallow continental seas. The view of the internal tide presented here is of a bottom boundary layer-driven frictional process. The commonly occuring coincidence of the interaction of the nitra- cline and bottom boundary layer over the inner shelf would act to enhance the vertical flux of nitrate.

Ch5. Conclusion

Finally, in Chapter 5, I provide final remarks on the broader context of the major findings of ISPX and then briefly discuss potentially fruitful future directions for research linking the physical dynamics of nutrient flux and the phytoplankton in system such as the Southern California Bight.

McKenna (2011)
"Blue whale response to underwater noise from commercial ships."

Committee:
Hildebrand (Chair)
Jay Barlow
Jim Leichter

In the Introduction chapter, she outlines Dissertation.
Each Chapter has a heading, a rationale/abstract, aims&objectives, and hypotheses tested.

Dissertation Structure
This thesis contains six empirical data chapters. Each of the chapters is intended to stand alone as a publishable unit, and the reader may encounter some redundancy in the introduction and methods for each chapter.

Chapter 2: Underwater Radiated Noise from Modern Commercial Ships
In chapter 2, I took an opportunistic approach to measuring radiated noise from ships by combining continuous seafloor acoustic data recordings with passage information from commercial ships transiting the SBC. Three metrics of ship noise measured during normal operating conditions are presented for seven merchant ship-types: container ships, vehicle carriers, bulk carriers, open hatch cargo ships, and chemical, crude oil and product tankers.

Chapter 3: Modeling Container Ship Underwater Radiated Noise
In chapter 3, seafloor acoustic measurements of container ship passages are combined with ship design characteristics, ship operational conditions, and oceanographic features to determine the variables relevant to observed ship radiated sound levels. Statistical models are developed for different frequency bands using the predictor variables.

Chapter 4: Quieter Ocean- Unintended Consequence of Recent Ship Traffic Trend
In chapter 4, I show how recent changes in commercial ship traffic along the west coast of the US, near the Channel Islands, had the unintended consequence of quieting a biologically important, yet urbanized coastal region. Long-term acoustic recordings (2005-2010) were combined with ship traffic information.

Chapter 5: Underwater Noise in a Blue Whale Habitat Near the Channel Islands National Marine Sanctuary
The goal of chapter 5 is to use long time-series data of ambient sound, combined with knowledge of ship traffic to understand the variability of the low-frequency sound fields in an important blue whale habitat. Both spatial and temporal comparisons at six sites in a coastal region off the coast of southern California are investigated. Differences in both the average ambient noise levels and the observed variability in levels between sites are quantified using three metrics: percentiles, empirical cumulative distribution functions and noise pollution levels. Furthermore, the variability in ambient noise levels at each site, are used to quantify the communication ranges for blue whale calls. For sites close to major shipping routes, temporal differences in noise levels related to ship traffic patterns are examined, including daily patterns and a recent shift in traffic in the region.

Chapter 6: Blue Whales Change their Calls in the Presence of Large Ships
In chapter 6, I investigate the response of vocalizing blue whales to the presence of commercial ships. Four potential vocal responses are investigated. First, changes in song are explored by quantifying inter-call intervals of the blue whale B calls during the seasonal peak of song. Second, patterns in song type in different average background noise levels were compared between October 2008 and October 2009. Third, changes in contact calls during foraging are examined by comparing the call interval of D calls in the seasonal peak in foraging (July 2008). Lastly, modifications to amplitude, frequency range and duration are measured for D calls.

Chapter 7: The Response of Deep-Foraging Blue Whales to the Presence of Large Ships
The goal of chapter 7 is to determine the response of individual deep-foraging blue whales to the close passage of large ships. The deployments of suction cup tags on individual blue whales within the shipping lanes provide acoustic and kinematic data. The behavioral reaction of the whale to the ship is then evaluated based on the tag data and previous descriptions of deep-foraging dives, while considering the characteristics of the passing ship (i.e., range to animal, size, speed, and source level), the individual animal (i.e., sex, behavior at close approach), and prey.

Munger 2007
"North Pacific Right Whale Calling Behavior and Habitat Characterization in the Southeastern Bering Sea"

Committee:
John A. Hildebrand, Chair
Jay P. Barlow
David M. Checkley
Paul K. Dayton
James A. Levin
Sue E. Moore
James H. Swift

The goals of this dissertation were to develop techniques for detecting North Pacific right whale calls in long-term acoustic recordings, to apply the results toward investigation of their seasonal occurrence and calling behavior, and to increase understanding of right whale habitat use in an oceanographic context. The results are reported in chapters 2 through 5 of this dissertation. Each chapter is intended to stand alone as a publication in a scientific journal, and may be somewhat redundant within the introduction and methods sections.

Ch 1. Introduction

Ch. 2. Performance of spectrogram cross-correlation in detecting right whale calls in long-term recordings from the Bering Sea
Chapter 2 discusses the development and evaluation of an automated call detection technique for finding right whale up-calls in large data sets. In contrast to species with highly stereotyped calls, such as blue whales or fin whales, right whales produce highly variable call types that increase in complexity with the complexity of the social interaction. We chose the simplest and most common call type, the up-call, on which to focus our detection efforts and as a reliable indication of right whale presence. Even within this call type, frequency and sweep characteristics vary substantially, and humpback whale calls also occur at similar frequencies making automatic detection a challenge. Chapter 2 was published in the journal Canadian Acoustics (Munger *et al.,* 2005) and is reprinted here with permission. The dissertation author was the primary researcher and author of this paper.

Ch 3. North Pacific right whale (Eubalaena *japonica)* seasonal and diel calling patterns from long-term acoustic recordings in the southeastern Bering Sea, 2000-2006
Chapter 3 describes the seasonal and daily calling behavior of North Pacific right whales in the Bering Sea. Interesting findings include the occurrence of right whales in the southeast Bering Sea later in the year than previously thought, and statistically significant patterns in diel right whale calling rates. Chapter 3 was submitted in full to the journal Marine Mammal Science. The dissertation author was the primary researcher and author.

Ch 4. Right whale 'up-call' source levels and detection ranges on the southeastern Bering Sea shelf
Chapter 4 determines source levels of right whale calls and detection range, based on two

different techniques for estimating distance to calling animals. The acoustic properties of right whale calls and effective detection range and distance estimates may prove useful in future estimates of abundance based on acoustic data. This chapter is in preparation for submission to Journal of the Acoustical Society of America. The dissertation author was the primary researcher and author.

Ch 5. Seasonal and interannual variability of North Pacific right whale occurrence and oceanography on the southeastern Bering Sea middle shelf: a conceptual model

Chapter 5 relates right whale occurrence to temporal variability in oceanographic habitat variables by comparing time series overlays of right whale calls and minimum abundance with temperature, salinity, chlorophyll concentration, ice retreat, and other data. A discussion is presented of possible linkages of seasonal, interannual, and longer- term climate variability to right whales via control of their primary prey, copepods. The dissertation author was the lead investigator and author of this chapter.

Stukel 2011
"Biological Control of Vertical Carbon Flux in the California Current and Equatorial Pacific"

Committee:
Michael R. Landry (Chair)
Mark Ohman (Co-chair)
Kathy Barbeau
Peter J. S. Franks
Andrew Scull

All chapters have been published, submitted, or in preparation.

Chapter 1 Contribution of picophytoplankton to carbon export in the equatorial Pacific: A re-assessment of foodweb flux inferences from inverse models
In Chapter One, entitled "Contribution of picophytoplankton to carbon export in the equatorial Pacific: A re-assessment of food-web flux inferences from inverse models," we addressed the controversial recent hypothesis that picophytoplankton- derived production dominates carbon export in the equatorial Pacific (Richardson et al. 2004; Richardson and Jackson 2007). Implicit in this ecosystem view is the assumption that picophytoplankton contribute to carbon export primarily through the gravitational sinking of ungrazed picophytoplankton, presumably after aggregation in marine snow particles. Using a new dataset from two equatorial cruises of the Equatorial Biocomplexity Program, we showed that picophytoplankton were not the dominant primary producers in the region and were almost completely grazed in the euphotic zone by protozoans. While they may have contributed to export in proportion to their role in primary production, this conclusion relied crucially on the assumption that all detrital particles (regardless of size) were equally likely to sink. A more nuanced portrayal of the detrital pool suggested instead that large phytoplankton contributed disproportionately to export and that sinking carbon existed primarily in the form of mesozooplankton fecal pellets. The paper based on this chapter has recently been published in Limnology and Oceanography (Stukel and Landry 2010).

Chapter 2 Trophic cycling and carbon export relationships in the California Current Ecosystem
Chapter Two, entitled "Trophic cycling and carbon export relationships in the California Current Ecosystem," builds on this idea that vertical carbon flux is largely dominated by mesozooplankton fecal pellets. To test the hypothesis that grazing processes largely determine carbon export within the region, we constructed simple trophic cycling relationships that predicted POC export, phytoplankton accumulation, and new production from phytoplankton growth and grazing measurements made on the 2006 CCE Process Cruise. These simple trophic cycling relationships were found to accurately predict simultaneously measured carbon export rates, suggesting that fecal production, rather than gravitational sinking of phytoplankton, was the dominant ecological process controlling carbon export. The paper based on this chapter is presently in review at Limnology and Oceanography.

Chapter 3 Do inverse ecosystem models accurately reconstruct food web flows? A comparison of two solution methods using field data from the California Current Ecosystem

Chapter Three, entitled “Do inverse ecosystem models accurately reconstruct food web flows? A comparison of two solution methods using field data from the California Current Ecosystem,” was primarily written to contrast two methods of solving under-constrained inverse ecosystem problems. In addition, it utilized ecological and biogeochemical data from two cruises of the CCE LTER Program to constrain an ecosystem model for eight different ecosystem states encountered during 2006 and 2997 spring cruises in the CCE. Sinking POC was estimated to be composed primarily of fecal material, with a smaller proportion of ungrazed phytoplankton sinking as well.

Chapter 4 Mesozooplankton contribution to vertical carbon export in a coastal Upwelling biome

Chapter Four, entitled “Mesozooplankton and vertical carbon export in a coastal upwelling biome,” addressed the same question of what constitutes sinking POC but more directly, using the results of sediment trap deployments on the 2007 and 2008 Process Cruises of the CCE LTER Program. Identifiable fecal pellets from sediment trap samples were enumerated and sized. Along with measurements of pigment sinking rates, the data suggest that fecal material was consistently a much greater proportion of the sinking material than ungrazed phytoplankton. While fecal pellets comprised the majority of flux in productive conditions, and particularly during the spring, sediment traps deployed during the fall contained a large proportion of unidentifiable marine snow aggregates. Mesozooplankton abundance profiles also showed that active transport by diel vertically migrating organisms was a significant portion of total carbon export.

Todd 2011
“Upper ocean processes observed by underwater gliders in the California Current System.”

Committee:
Daniel L. Rudnick, Chair
Bruce D. Cornuelle
Peter J. S. Franks
Stefan G. Llewellyn Smith
Clinton D. Winant

Introduction

Ch 2. Monitoring the greater San Pedro Bay region using autonomous underwatergliders during fall of 2006

Ch 3. Poleward flows in the southern California Current System: Glider observations and numerical simulation

Ch 4. Underwater gliders reveal rapid arrival of El Nin ˜o effects off California’scoast

Ch 5. Upper ocean thermohaline structure in the California Current System

(Intro narrative was too unstructured to include).

Vilchis 2010

"A retrospective study of ecosystem effects of the 1976/77 regime shift in the eastern Pacific warm pool"

Committee:
Lisa T. Ballance, Chair
Michael R. Landry, Co-Chair
David M. Checkley
John A. McGowan
Dean Roemmich
Mark H. Thiemens

I combined this with measurements taken from historical specimens collected within the eastern Pacific warm pool during the 1960–2006 period that have been held in museum collections of the United States and Mexico. I then analyzed trends in the time series of stable isotope ratios to determine whether correlations existed with time and in response to the 1976/77 regime shift. These analyses and results are described in Chapters 2–4, and have been prepared for publication in the peer-reviewed literature. They are intended to be stand-alone documents; thus some material in each may be repetitive. To conclude, Chapter 5 summarizes the results of the dissertation and proposes possible avenues for future research.

Ch 2. Temporal variability of neustonic ichthyoplankton assemblages of the eastern Pacific warm pool

Ch 3. Bottom-up forcing of a tropical mid-trophic community

Ch 4. Analysis of long-term diet changes in tropical seabirds