To Fish or not to Fish:
Challenges of managing culturally and ecologically important species

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1. Summary

The harvest, management, and cultural use of abalone have spanned millennia and geographies along the eastern Pacific. In Haida Gwaii, abalone hold special ecological, cultural, spiritual, economic, and historical significance. This case study will explore how this significance is communicated and interpreted within management decision making. Students will read and interpret multiple sources of knowledge and synthesize these disciplinary and interdisciplinary perspectives into a common understanding of the abalone socio-environmental challenge. Students will grapple with how to make a management decision about abalone harvest within the context of complex cultural, legal, and scientific understandings of the issue.

2. Courses This Case May Be Appropriate For:

- Conservation Biology Ecology / Earth Systems Social-Ecological Systems
- Indigenous Peoples and the Environment Ethics and the Environment
- Coastal Processes and Management

3. Target Student Audience

Upper-level undergraduates and graduate students

4. Socio-Environmental Synthesis Learning Goals

1) *Understand the structure and behavior of socio-environmental systems.*

   This case requires students to create conceptual models of a socio-environmental system and identify key socio-ecological components and feedbacks within the system. Students will understand the key issues and feedbacks between natural resources, users of those resources, and the managers and decisionmakers who govern them by reading, discussing, and synthesizing disciplinary and interdisciplinary perspectives on the system.

2) *Consider the importance of scale and context in addressing socio-environmental problems.*

   Students will deconstruct the socio-environmental system by evaluating knowledge sources from varying ecological, socio-cultural, and political timescales. Students will grapple with the challenges of, and solutions for, abalone management with and without sea otters, considering different social preferences, and given the political and ethical realities of marine management in a First Nations co-management system. Importantly, there are different knowledge holders and stakeholders— such as a local resource user; a regional, commercial resource user; or a federal-level decisionmaker— that view the system at different scales. These include temporal (e.g., millennia of traditional resource use vs. a few centuries of commercial trade of natural resources) and spatial (e.g., geographic, cultural, and economic distribution of resources) scales, which will influence how stakeholders perceive equitable and sustainable resource use.

3) *Co-develop research questions and conceptual models in inter- or trans-disciplinary teams.*

   Students will read a range of scientific, management, and traditional knowledge literature and assess how these various knowledge sources can inform decision making, identify knowledge gaps within disciplinary and interdisciplinary perspectives on the

issue, and communicate disciplinary and interdisciplinary problem statements and solutions. This case study requires students to evaluate a socio-environmental challenge from both disciplinary and interdisciplinary perspectives and synthesize a potential management solution within teams from various types of information sources. Identifying knowledge gaps will require students to generate research questions that, if answered, would help fill those gaps and provide critical information to decisionmakers.

4) *Find, analyze, and synthesize existing data, ideas (e.g., frameworks or models), or methods.*

The harvest, management, and cultural use of abalone have spanned millennia and geographies along the eastern Pacific. In Haida Gwaii, abalone hold special ecological, cultural, spiritual, economic, and historical significance. This case study will explore how this significance is communicated and interpreted within management decision making. Students will read and interpret multiple sources of knowledge and synthesize these disciplinary and interdisciplinary perspectives into a common understanding of the abalone socio-environmental challenge. Students will grapple with how to make a management decision about abalone harvest within the context of complex cultural, legal, and scientific understandings of the issue.

5. Learning Objectives

1) Students will be able to identify management-relevant components of abalone ecology and ecosystem dynamics, Haida culture and worldview, and the social history and significance of abalone for Haida and non-Haida.

2) Students will understand the key issues and feedbacks between natural resources, users of those resources, and the managers and decisionmakers that govern them.

3) Students will translate information among relevant perspectives (e.g., scientific, social, economic, or political).

4) Students will link ecological dynamics of abalone management and the social and cultural dimensions of abalone management together through individual and group conceptual models and reflection.

5) Students will reflect on their normative understanding of this socio-environmental case study and how that perspective may conflict with various stakeholders' livelihoods and beliefs.

6) Students will read and interpret information from various, credible sources, and evaluate how those sources of knowledge can be used in decision-making.

7) Students will have more insight into the scientific and socio-cultural complexities of socio- environmental problems.

8) Students will understand the need for multiple perspectives and ways of knowing in order to identify trade-offs associated with viable solutions in this and other socio-

environmental challenges.

9) Students will engage in open dialogue with peers and experts around the challenges and opportunities of interdisciplinary collaboration.

How our learning objectives achieve the four SES learning goals:

Goal	Learning Objectives	Case Study Activity
Understand the structure and behavior of socio-environmental systems	(1), (2), (4), (5), (7)	Phase I: Learning the System Phase II: Synthesizing the Socio-Environmental Challenge Phase IV: Final Discussion
Consider the importance of scale and context in addressing socio-environmental problems	(1), (2), (4)	Phase I: Learning the System Phase II: Synthesizing the Socio-Environmental Challenge Phase III: Stakeholder Perspectives Phase IV: Final Discussion
Co-develop research questions and conceptual models in inter- or trans-disciplinary teams	(6), (8), (9)	Phase I: Learning the System Phase II: Synthesizing the Socio-Environmental Challenge
Find, analyze, and synthesize existing data, ideas (e.g., frameworks or models), or methods.	(3), (6), (8)	Phase I: Learning the System Phase II: Synthesizing the Socio-Environmental Challenge

6. Introduction

Along the isolated, foggy shores of Haida Gwaii, British Columbia, a glimmer of pearl flashes in the intertidal zone, where the sea meets the shore. A closer look reveals a group of snails, hunkered down under the kelp fronds. We've had a glimpse of the northern abalone, a treasured mollusc, prized worldwide both for its beautiful shell and as a culinary delight.

An animal with a storied past and an uncertain future has many names: Galgaahliiyaang. Haliotis kamtschatkana. Northern abalone. The different names reflect the discrepancy in how people would like to use, manage, and gain access to this animal: A vital food source, a last meal, sustenance for an iconic and charismatic species, an economic commodity, an endangered species, and the source of pesky political controversy.

Despite its quiet lifestyle, this snail has been an active part of the cultural and biological landscape of these shores over the thousands of years the native Haida people have harvested the northern abalone. "We used to just go pick what was above... the water line, because they'd be crawling around in the kelp. And we wouldn't touch anything else that's in the water," observed Haida local, Martin Williams (Haida Gwaii Traditional Knowledge Study 2011).

But abalone populations in Haida Gwaii, and across British Columbia, are dwindling due to overharvest. Abalone is a highly valued commodity, is easily accessible, and requires low capital investment to exploit. As a result, intense commercial fishing and poaching in recent decades has led to the widespread decline of abalone across British Columbia and, despite a moratorium on fishing in 1990, northern abalone became the first marine invertebrate listed by the Committee on the Status of Endangered Wildlife in Canada as threatened in 1999 and endangered in 2009 (Fisheries and Ocean Canada 2007).

For the Haida people, the decline of abalone and closure of the subsistence harvest is a profound loss. As one Haida elder explained, "Many, many of [our elders] including my late father, one of the last things they asked for or were wishing for was abalone. My birth mother who wasn't even that fond of it before, one of her last requests was to have some abalone. And it hurt very much that we couldn't give it to them, I must say. Because we like to fulfill their last wishes, but we could not fill that one, because the [abalone] was overharvested, severely" (Haida Gwaii Traditional Knowledge Study 2011).

To complicate matters, sea otters, formerly harvested to local extinction in Haida Gwaii during the fur trade of the 1800s, are poised to return to the archipelago's shores (Sloan and Dick 2012). As a predator to the northern abalone, sea otters impact their population size, and some scientists claim their presence will unequivocally prevent the recovery of abalone to population levels that will support sustainable harvest (Watson 2000). Sea otters are threatened under the federal Species At Risk Act (S.C. 2002, c. 29) and many within the Haida Gwaii tourism industry advocate for the species' return.

Today, northern abalone remain threatened by man-made and environmental stressors: illegal poaching, the decline of rocky kelp bed habitat, and changing ocean currents and temperatures (Fisheries and Ocean Canada 2007). Studies in the last few years indicate that the species may be recovering—some populations in Haida Gwaii are reaching the recovery targets the Department of Fisheries and Ocean (DFO) set within the Abalone Action Plan (Haida Gwaii Northern Abalone Community Action Plan 2003). In response, Haida people are optimistic about the possibility of opening an abalone fishery for traditional food and ceremony use only. However, other stakeholders have tempered optimism around the viability of population recovery, the equity of resource rights and access, and the enforceability of management actions.

Students will explore this complex social-ecological system and management challenge within individual reflection, group exercises, and interactive problem-solving activities. Students will map the socio-environmental system of abalone ecology and Haida and non-Haida preferences around abalone management within a 'system concept map'. Students will add to this map as they learn and synthesize additional disciplinary and interdisciplinary perspectives. Students will identify relevant stakeholders within the system and evaluate their respective interests. Finally, students will reflect on the complexity and interdisciplinary challenges of socio-environmental synthesis; its value when identifying viable solutions to a management challenge; and their own perspectives on an ethical, political, and socio-ecologically complex real-world problem.

This case study can be modified to span a minimum of two and a half hours, or it can be expanded to span multiple weeks of instruction. The case will likely fuel rich discussion within an interdisciplinary classroom and students will be introduced to socio-environmental synthesis and the basics of environmental management.

7. **Classroom Management**

Phase I: Learning the System (30 minutes + homework)

Goal: Build understanding around the abalone management challenge through a specific problem frame and system assessment; critically evaluate a data source.

The class is divided into six groups (minimum 2-3 individuals in each group; there may be fewer groups if the class size is smaller, preferred readings for a reduced number of groups (minimum of three groups) are in blue below). Each group is given one reading and a series of questions. We recommend assigning readings to groups with a different disciplinary background from the reading they are designated. Depending on your students and their comfort with primary scientific literature, consider priming them to skim the articles with the homework questions specifically in mind.

1) **Academic/archeology:** Sloan, N. 2003. Evidence of California-Area Abalone Shell in Haida Trade and Culture. *Canadian Journal of Archeology* 27(2): 273-286.
2) **Media/Cultural and Social Politics:** Ramsey, Heather. "The Great Abalone Theft" *The Tyee.* May 2007 http://thetyee.ca/News/2007/05/09/Abalone; Ha-Shilth-Ha. "DFO Puts Abalone Project At Risk". December 2005 http://www.hashilthsa.com/archive/news/2012- 08-15/dfo-puts-abalone-project-risk
3) **Federal Management:** Fisheries and Oceans Canada. 2007. Recovery Strategy for the Northern Abalone (*Haliotis kamtschatkana*) in Canada. *Species at Risk Act* Recovery Strategy Series. Fisheries and Oceans Canada, Vancouver. *vi* + 31 pp.
4) **Academic/Natural Science:** Watson, J. 2000. The effects of sea otters (*Enhydra lutris*) on abalone (*Haliotis* spp.) populations *in* Campbell, A. (*Editor*) *Workshop on rebuilding abalone populations in British Columbia.* Can. Spec. Publ. Fish. Aquat. Sci. 130: 158 p.
5) **Traditional Knowledge:** Haida Gwaii Traditional Knowledge Study. Excerpts from Volumes 3. August 2011. Prepared for Council of the Haida Nation by Haida Marine Traditional Knowledge Study Participants, Janet Winbourne, and Haida Oceans Technical Team, Haida Fisheries Program. [Students should read introduction and Northern Abalone section]
6) **Local Management:** Haida Gwaii Northern Abalone Community Action Plan. Adopted September 2003, Updated March 2008

Consider also sending a primer on concept mapping to your students ahead of class. This site may be useful for instructors that have not used concept mapping before. Here, here, and here are different examples for how a concept map might be constructed that may open students' minds to various map structures. The following is a definition of 'concept map' you may provide to your students if that is helpful: A hierarchical, structured diagram that illustrates conceptual knowledge and the relationships between concepts for a specific topic.

Students will answer these questions on their own as homework (an answer key can be found on page 18):
1) What are 2-3 takeaways from the article(s)?
2) Write a problem statement for the abalone management challenge. What is the conflict and for whom?
3) Explain how confident you are in the source of information and why.
4) Identify key knowledge gaps remaining after reading this article. What additional information do you need in order to create a viable solution to the problem of abalone management in Haida Gwaii?

At the beginning of the class, students are divided into their groups and having read the same article, share their reflections to their homework questions.

Discuss individual answers to the homework questions	10 minutes
Draw a concept map of the abalone socio-environmental challenge, using the article and student problem statements as a frame	20 minutes

Instructor Notes:
Consider prompting student groups to discuss the following questions:
1) How would you characterize the abalone management challenge, given the information you have? What types of knowledge do you have access to at this point?
2) What types of knowledge did you trust and why? What about the data or the way the author(s) of your article presented the data influences your confidence in the outcomes (e.g., ecological data vs. journalism/enforcement information vs. social interviews). [Learning objectives 2, 3, and 6]
3) What are the ecosystem services that abalone provide to people? (E.g., cultural identity, spirituality, livelihoods, conservation values, food provisioning, intrinsic value, or support for intact ecosystem (sea otter prey)). [Learning objective 2]
4) What are some of the key challenges for managing abalone from your disciplinary perspective? [Learning objective 1]

Assessment Goals:
There is no formal assessment for this section of class time. However, instructors may circulate the classroom to get a sense of how students are achieving the following three goals. If students are struggling, consider having them write "one thing you find confusing or difficult" and "one thing you find interesting or novel" on a notecard. Instructors may then use these notecards to gauge how students have felt interpreting their articles (e.g., are students struggling with facts or are they struggling with how their article links to broader issues of management, ethics, and ecological health?). This same activity can be used after Phase III to evaluate how students have advanced their understanding (e.g., have students moved from struggling with disciplinary perspectives to struggling with a systems perspective?).

1) Do students have a grasp of their assigned disciplinary perspective of the problem?
    - Are they articulating key takeaways from their assigned articles?
    - Are they discussing the limitations of their assigned articles?
2) Are students distilling the key takeaways in the context of the broader socio-environmental system and management problem?
    - Are students connecting their articles to conceptual themes (e.g., how the disciplinary perspective of their article may inform a management decision, how their article may inform or fall short of informing how use rights could be equitably distributed)?
    - Are students highlighting information relevant to the management challenge (e.g., linking historical trade and use of abalone to current cultural significance)?
3) How are students representing information or knowledge within group discussion?
    - Are students articulating both the value and limitations of the articles? (e.g., if representation of the cultural and spiritual importance of the abalone within Haida history is not being integrated into discussion, consider proposing ways archeological data may play an important role in influencing social preferences and use of abalone).

Phase II: Synthesizing the Socio-Environmental Challenge (1 hour)

Goal: Build understanding around the abalone management challenge by analyzing disciplinary and interdisciplinary perspectives.

Groups pair up followed by discussion around reconciling problem frames. Groupings:
1) Watson 2000 + Traditional Knowledge Study
2) Community Action Plan + Tyee and Ha-Shilth-Ha articles
3) Recovery Strategy + Sloan 2003

Groups present their key takeaways and concept map to each other	5 minutes
Groups discuss the question: Where are key points of conflict in the two group concept maps (e.g., differing linkages, differing focal components of the system)? How does the other group's map add critical information to your group's understanding of the abalone management challenge?	10 minutes

Groups re-divide into a larger group. Groupings:
1) Watson 2000 + Tyee and Ha-Shilth-Ha articles + Recovery Strategy
2) Traditional Knowledge Study + Sloan 2003 + Community Action Plan

Groups present their key takeaways and concept map to each other	10 minutes
Groups discuss the question: Where are key points of conflict in the three concept maps (e.g., differing linkages, differing focal components of the system)? How does the other groups' maps add critical information to your group's understanding of the abalone management challenge?	15 minutes

Class reconvenes as a whole group to synthesize a common understanding of this socio-environmental challenge.

Discussion questions: 1. How does the original source of knowledge from which you frame the problem determine or influence your perception of the abalone challenge? 2. Did your perspective shift with the integration of new types of information? Why or why not? 3. How do your personal points of view affect your perception of the abalone management challenge?	20 minutes

Instructor Notes:
Instructors may probe students again around their confidence in various sources of information. When students are integrating ecological and traditional knowledge, how are they weighing those information sources? How are they comparing methods used within their respective readings? Ask students to reflect on and articulate points of conflict as they shared out their concept maps to each other: what were major differences or similarities between the organization, concepts, and linkages? [Learning objectives 1, 2, 3, 4, 5, and 8]

Assessment Goals:
During the discussion, consider the following questions. Depending on how you interpret students' responses and synthesis, you may push them to reflect further to achieve the learning objectives listed above.

1) How does disciplinary perspective influence trust and use of information? (e.g., students who have read the ecological study have a different perspective and focus than those that have read other sources of information/perspectives)
2) Are students aware of disciplinary or personal perspectives influencing their argument? (e.g., are students articulating the influence of their initial reading on their point of view of the abalone management problem and the social-ecological system? are they arguing based on personal perspective or a particular stakeholder group?)
3) How are students comparing methods used within their respective readings? (e.g., are they weighting different methodologies as more relevant or trustworthy?)
4) Are students open to new information sources and shifting perspectives based on additional points-of-view, based on small- and larger-group discussion and edits to concept maps?
5) Are students linking concepts of both ecological and social-cultural dimensions? (e.g., do students articulate clear links between abalone biology and traditional harvest methods)
6) Are students articulating discomfort or comfort with the process of integration?

If you would like students to more deeply reflect on any one of these questions, consider asking them to write for one minute in response. For example, questions could include:
1) How do you see your own beliefs and perspectives influencing your concept map and discussions?
2) What sources of information do you trust the most and why?
3) What types of linkages are you making between ecological and social perspectives on the abalone issue?
4) What has made you most and least comfortable in this case study thus far?

Phase III: Stakeholder Perspectives (1 hour)

Goal: Understand and value multiple stakeholder perspectives

This segment will begin with a group brainstorm of relevant stakeholders within the abalone management challenge.

Group brainstorm: What are the various individuals or groups that have a stake in this management challenge?	5 minutes

Write each stakeholder group on a different whiteboard/flipchart around the room. Five stakeholders may work well for a class of ten (2 students per group); up to eight stakeholders may work for a class of 30 (4-5 students per group). Groups should be different from previous groups in order to disseminate disciplinary understandings of the issue.

Stakeholders may include: Haida subsistence fisher, non-Haida recreational fisher, non-Haida commercial fisher, DFO representative, environmental scientist, Haida citizen, tourist operator, etc.

Each student group is stationed at a flipchart. Students are instructed to write 1-2 interests (i.e., their underlying interests driving their involvement in the abalone management challenge) for each stakeholder, moving to a new stakeholder flipchart every 2-3 minutes. They may not add an interest that has already been written by a previous group.	15 minutes
Once the groups have transitioned to all of the charts, the groups present out on the stakeholder chart they are stationed at by reading the interests that have been listed on the flipchart.	10 minutes
Group discussion: In order to digest the various overlapping and potentially conflicting stakeholder interests, ask the students to consider how they might collaborate to reach a decision mutually agreed upon by the various stakeholders, based on the knowledge sources they have explored and the stakeholder perspectives they have identified. How might you structure a process for equitable decisionmaking? What barriers to equitable decisionmaking might they face in the collaboration?	10 minutes

Students are given three potential management options and are asked to reflect individually, in writing, on how they may choose one of those options.

Three management options:
  1) Permanent moratorium on wild capture abalone fisheries in Haida Gwaii but allow abalone aquaculture
  2) Opening the abalone subsistence fishery for Haida natives only
  3) Opening a limited abalone commercial and/or recreational fishery in Haida Gwaii if abalone is recovered in 5-10 years; exclude sea otters from Haida waters
Questions to consider in written reflection:
  1) Is there an additional management option you feel strongly about adding to this list?
  2) What are two social and environmental trade-offs implicit within the management option you chose?
  3) How does this management decision meet the interests of some stakeholders and not others?
	10 minutes

Share decisions.	10 minutes

Instructor Notes:
  1) Consider how students are integrating and preferring various social perspectives. For example, Non-Haida recreational fishers on the Island also remember a time when abalone was plentiful and they could have it at the dinner table. Additionally, non-Haida traders were integral to bringing California-area abalone shells to the Haida, which led to the widespread use and valuation of abalone within Haida clothes, decoration, and even family crests. How are students weighing these system influences when considering user rights and values?

2) Observe how students are empathetically connecting with various stakeholders and how that impacts their consideration of stakeholder interests or management options. Consider raising these observations in the final discussion when talking about interdisciplinary collaboration and disciplinary perspectives on a socio-environmental challenge.
3) How have students considered the practical and legal challenges of particular management options? Consider introducing them to a few of these practical limitations in order to raise their awareness around the complexities of decision making (e.g., inability to properly enforce fishery regulation given lack of patrol boats and agency capacity to implement particular management options). Could farming abalone allow for First Nations food, social and ceremonial enjoyment of abalone without impacting wild populations?
4) Consider raising issues around the ethical dimensions of various management options (e.g., Haida historical use and rights to their resources, and the cultural legacy of colonization; the complexities of both Haida and non-Haida overuse of resources) [Learning objectives 2, 5, and 8]

Assessment Goals:
There is no formal assessment for this section of class time. If students completed notecards following Phase I, distribute another set of notecards to evaluate how their learning has progressed ("one thing you find confusing or difficult" and "one thing you find interesting or novel"). Have students moved from struggling with disciplinary perspectives to struggling with a systems perspective? Are students articulating excitement about new ideas, as related to their own interests?

The following questions—that instructors may evaluate informally during class discussion—seek to probe how students are integrating case study knowledge from a socio-environmental synthesis perspective.
1) Are students grappling with the range of possible solutions and evaluating various social and environmental trade-offs within those solutions?
2) Are students identifying conflicting interests and trade-offs?
3) Are students thinking about spatial scale and context in their observations of the problem (e.g., sea otter reintroduction, climate change; spatial variation in abalone habitat distribution; issues of access to resources that may be scale-dependent; legal concerns of opening a fishery in Haida Gwaii if recovery hasn't occurred across the range)?

Phase IV: Final Discussion (1 hour)

Goal: Synthesize the challenges and opportunities of interdisciplinary systems thinking and problem-solving.

Group discussion	30 minutes

Reconvene the class for a final synthesis discussion. Here are a number of possible discussion questions that can be adapted based on the prioritized learning objectives.

1) Which stakeholders should be entitled to harvesting rights?

- How should spatial variation in the abalone population and historical human inequities be reflected within these rights?
- How can enforcement be implemented equitably and with accountability, given resource and capacity constraints?

2) What does recovery look like from the point of view of different knowledge holders?
- If stewardship succeeds in restoring Haida Gwaii populations, but fails in other regions of the British Columbia coast, would that mean that Haida Gwaii residents must wait (for lifting of the closure) until the populations in other regions improve sufficiently? Or, could some regional exceptions be made in a flexible delisting process? Would protecting abalone in some areas lead to enhanced larval settlement in adjacent areas that could eventually support some level of noncommercial fishing (aboriginal or recreational)?
- How might future climate change affect abalone recovery (e.g., ocean acidification, hypoxia, ocean temperatures)?
- What would recovery of northern abalone "look like" if sea otters return and crop abalone populations to low levels (i.e., benchmarks or indicators)?
- What does recovery mean for the management of sea otters, competitors to the human harvest of abalone and valued differently by Haida subsistence users and tourist interests?

3) How should ecosystem services and values be considered within decision making?
4) Would you come to different conclusions if you were looking at this challenge at a different scale or within a different context?
5) What lessons can you draw from this case study to think about other socio-environmental system challenges?
6) How have you seen decisions made in the face of social and ecological trade-offs, particularly when there are inequities in access, values, and impacts?
- Under what conditions does equity play a role in decisions within socio-environmental systems?
7) When were you most comfortable or uncomfortable during this case study?
- What was challenging about the interdisciplinary nature of your team discussions?
- How did your reflections on the overlapping perspectives of the management challenge influence your influence your perception of the "solution"?

Redraw your concept map of the socio-environmental system in Haida Gwaii around abalone management.	10 minutes

After students have completed their new concept map, have them reflect on the case study overall. Students take time to reflect, in writing, on the following assessment questions.

Encourage them to take their time and provide thoughtful responses.	10 minutes

1) Socio-environmental problems have been called 'wicked' because they are so complex. Why is it so difficult to resolve these issues?
2) You were exposed to data from several different disciplines. How did using different datasets affect your perception of the problem and the possible solutions? Why is it

relevant to assess different types of data when considering different environmental policy and management options?
3) We included information from a wide range of data sources in our fact sheets. Which types of information sources are most useful/which do you trust the most? Which are least useful?
4) Look at the two concept maps you created at the beginning and end of this case study. What changed? What elements of your second map reflect a greater understanding and/or synthesis of the abalone socio-environmental challenge?
5) What did you find to be the strengths of this case study?
6) What would you change to improve your learning experience during this case study?

Conclusion: Ask students to reflect on how their concept maps have shifted over the course of the case study. 1. What changed? 2. What elements of your second map reflect a greater understanding and/or synthesis of the abalone socio-environmental challenge?	10 minutes

8. Background

Northern Abalone Life History and Ecology Northern abalone (Haliotis kamtschatkana) is the northernmost Haliotis species, occurring from Baja California to Yakutat, Alaska, and is the only abalone species in British Columbia (Sloan and 13 Breen 1988). Although knowledge of its life history is limited, generalizations can be inferred from other abalone species, as the biology of this group is relatively uniform. Adults occur in patches on rocky reef-kelp forest habitats of outer coasts from the very low intertidal to ~12 m depth, where they graze attached and drift algae (Sloan and Breen 1988). Population size characteristics vary according to a habitat's wave exposure regime and kelp forest species, with smaller adults associated with habitats of high wave energy (Lessard and Campbell 2007), and higher abundance associated with areas that have low to medium wave exposure and boulders (Rogers-Bennett et al. 2011).

In particular, abalone growth rates tend to be highest in giant kelp beds (*Macrocystis integrifolia*) and decline in the presence of the bull kelp (*Nereocystis luetkeana*) and understory kelp (*Pterygophera californica*) that dominate in wave exposed areas and areas where sea otters are present (Wallace 1999; Watson & Estes 2011; Martone and Markel, unpublished data). Northern abalone live more than 20 years (Shepherd et al. 2000) and are semi-sedentary, moving hundreds of meters within a year (Sloan and Breen 1988). Because they are broadcast spawners and have short-lived (<8 days), non-feeding larvae, abalone populations need to have sufficiently dense clumps for successful fertilization of their gametes (Sloan and Breen 1988). Local populations may, therefore, be composed of discrete subpopulations distributed according to appropriate rocky habitat and linked by (limited) larval dispersal. Thus, the key to sustaining their populations is to maintain sufficient densities of adults, patches of subpopulations that are physically proximate, and connectivity among patches of adults via larval transport. Because of these requirements, abalone species respond well to area protection and readily increase in density, average body size, and reproductive output when they are in higher densities in refugia from predators like sea otters (Wallace 1999, Sloan 2004).

Critical habitat is identified in the abalone action plan to the extent possible using the best available information, including attributes such as salinity, wave action, rugosity, crevices, coralline algae, kelp availability, and substrate type (Fisheries and Oceans Canada 2012). Abalone are normally found attached to rocks, boulders, bedrock or other stable substrates at depths of < 10m, and in a water column that exhibits moderate to high sea water exchange. Boulders and bedrock provide allows for attachment for both the abalone and for macroalgae, which provides food and cover for adults. Abalone require waters with salinity >30 ppt, and are therefore not found near areas of freshwater run-off or in estuarine habitats. Coralline algae is another important feature for abalone, as the presence of coralline algae is the primary settlement cue for the larvae of Northern Abalone and provides food for the juveniles prior to their transition to a macroalgal diet.

The presence of sea otters are also key drivers of abalone populations. Sea otters are the only marine mammal that doesn't have blubber and therefore must maintain a high metabolic rate, requiring individuals to eat up to one-third of their body weight per day (Watson 2000). To meet this metabolic demand, sea otters are voracious predators of marine invertebrates including abalone, sea urchins, clams, mussels, crabs, snails, cucumbers, and seastars that share the semi-exposed nearshore rocky habitat. Despite high levels or predation pressure, some recent evidence exists that abalone can persist in the presence of sea otters, although at reduced densities (Micheli et al. 2008). First, by foraging on sea urchins, sea otters provide abalone and other marine species, including other invertebrates and fishes, with ample kelp forests for shelter, food and reproduction (Markel 2011, Watson & Estes 2011). Some hypothesize that the reintroduction of sea otters also changes abalone behavior, forcing them to aggregate more in crevices, and in so doing, increase their chance of both reproductive and foraging success due to reduced mortality from other predators (e.g., seabirds, seastars, octopus) (Wallace 1999, Micheli et al. 2008). In the absence of sea otters, abalone have likely increased in overall abundance, but may have expanded their distribution to more open habitats in the absence of high predation. This may lead to decreased fertilization success due to reduced clumping of adults, especially when combined with commercial harvesting pressure. The positive effects of sea otters on abalone populations via increased aggregation of abalone in crevices despite reduced overall population size is also supported by the co-existence of otters and abalone on evolutionary time scales. For thousands of years, northern abalone populations lived in balance with the sea otter (*Enhydra lutris*).

About 100 years ago, the sea otter was hunted to extinction across its range, including along the shores of Haida Gwaii (Sloan 2004). As a result of their absence, sea otter prey species, including abalone and red sea urchins, thrived and multiplied. Over time, the subtidal extent of kelp beds decreased as sea urchin grazing progressed unabated. The ecological system in the semi-exposed nearshore rocky habitat in Haida Gwaii today, in the absence of sea otters, is very different than that which existed in the presence of healthy sea otter populations. In deeper time, sea otters were likely abundant in these regions and were hunted extensively by the Haida and other First Nations across the west coast of North America (Watson 2000), as evidenced by their bones in midden sites across British Columbia (Szpak et al. 2012). Localized hunting of sea otters around Haida village sites may have maintained predator-free areas in the vicinity of village sites, allowing abalone and urchins and other invertebrates to increase and be available for human use (Watson 2000), although evidence for urchin and abalone in midden sites ranging from 2000-13500 years ago is scarce (Szpak et al. 2012). However, excluding sea otters in areas is challenging, given the fact that otters are protected as Species of Special Concern under the Species at Risk Act (SARA) and there is negative popular opinion about sea otter hunting. For example, management of sea otters in Southern California is costly and time-consuming, so managers recently have chosen to stop re- locating otters that are invading areas south of Point Conception and have allowed otters to re- establish naturally.

Haida Tradition

First Nations along the Pacific Coast, including the Haida, have relied upon Northern Abalone for food, social and ceremonial purposes over countless generations (Haida Gwaii Traditional Knowledge Study 2011). Abalone (*Haliotis* spp.) shells in coastal middens provide evidence of the pre-historic dietary and cultural importance of abalone (Sloan 2006). Shells from California red abalone are also used as decoration on ceremonial dress and artwork in many regions of B.C., and were traded throughout the Northwest Coast for decoration and currency (Sloan 2003). This food source is no longer available due to coast-wide fisheries closures as a result their extremely low abundance and unsustainable decline.

Haida relationships with the natural (and supernatural) world are communicated through stories that describe their worldview and teach about balance between people and nature (Haida Gwaii Traditional Knowledge Study 2011; Wilson and Harris 2005). Haida creation stories tell that the Haida came from the sea and that their history and experiences are linked to sea creatures, thus the stories emphasize the importance of respect for all sea creatures, particularly in the harvest of seafoods. Overharvest is seen as both disrespectful and short-sighted: "... a lot of times we only took half a sack and...kept that for while we were moving back and forth, doing our gathering, food- gathering there... grandmother used to say, 'Only take enough for what you need. You don't need to take any more than that.' Hence, they were very concerned about preserving things like that, making sure that we had enough. I know grandmother ... always told us, 'Never get too greedy about that. If you look after it, it will always be there.'" (HMTK Study participant, Mar. 2007).

The Haida reinforce these ideas and conservation ethic through their traditional harvesting methods. The Haida harvested northern abalone for food along rocky intertidal shores throughout Haida Gwaii, hand picking animals exposed in the intertidal at low tides and spearing animals down to six feet below the water surface (Ellis and Wilson 1981). The traditional tools was a two-pronged seafood spear, made by lashing two sharpened pieces of huckleberry stem using spruce root twine around each side of a long pole made of spruce or red cedar. Collection of abalone using this spear required practice and skill. Abalone can adhere to the rock with their strong foot and once this happens the individuals are difficult to pry off; thus, the animals must be speared and twisted off the rock in the same motion. If speared too lightly, the abalone could be knocked off the rock and fall away to depths beyond reach. This method of collection was slow and deliberate, and in concert with the preservation ethic, allowed a long-history of First Nation abalone harvest.

Northern Abalone Commercial Fisheries

In British Columbia, First Nations exploitation of abalone has occurred for thousands of years, but the commercial abalone fishery didn't begin until 1972. Commercial landings peaked in 1977 around 474,000 kg (Fisheries and Oceans Canada 2007, Watson 2000). In response to declines, DFO implemented regulations to control effort, including the introduction of limited entry in 1977 and a total allowable catch (TAC) in 1979, followed by individual licenses (Sloan 2004). Note that none of the 29 licenses for abalone were held by Haida people. Despite the implementation of TACs, abalone stocks continued to decline through the 80s and, in response, the commercial fishery was closed in 1990, along with any take of abalone, including harvest by First Nations. All harvest of abalone remains closed throughout British Columbia. Further declines in abalone, due to a variety of factors including illegal poaching, led to the species being listed by the Committee on the Status of Endangered Wildlife in Canada (COSEWIC) as threatened in 1999, as threatened under SARA in 2003, and, most recently, in 2010, as endangered by COSEWIC.

In California, the picture is similar. Commercial fisheries for abalone across much of North America exhibit rapid increases in landings, followed by precipitous declines, and then closure of commercial harvest for a variety of reasons, including overexploitation, disease, episodic recruitment, and predation (Watson 2000). The first commercial fisheries for abalone began earlier, starting in the mid-1800s when Chinese fishers harvested abalone from the intertidal and shallow subtidal zones and shipped the product dried or canned to Asia. Advanced technology, including SCUBA and rubber suits, allowed the fishery to expand to deeper waters and led to more intensified harvest in California, British Columbia and Alaska in the 1970s (Estes and VanBlaricom 1985). As in British Columbia, harvest restrictions were implemented in the 1980s, but by 1997, abalone harvest was completely prohibited across most of California due low stocks in part from overfishing (Watson 2000).

Northern Abalone Recovery and Management
Direct take through poaching continues to be the major threat to abalone population recovery. Seizures of illegal abalone take, including a few high-profile convictions of Haida Gwaii residents for poaching along the North Coast in 2007, indicate that poaching is widespread and target all size classes. Poaching is a particularly hard to combat due to the difficulty of enforcing fishing regulations on a coastline that is extensive, rugged, and isolated. Moreover, in some Haida and other First Nation communities, small takes of abalone for personal consumption occurs, and this may have cumulative effects on depleted abalone populations, even if the catch is limited. Community awareness about the status of abalone populations and community willingness to take action to restore abalone are vital to rebuilding efforts (Jones et al. 2004).

There are few other human activities that directly impact abalone, although activities of concern include finfish aquaculture, log booms, dredging, the construction of underwater pipes or cables, and installation of pilings that can affect critical habitat. Abalone recovery activities must consider these impacts, and potential mitigation measures, when evaluating and implementing abalone restoration (Lessard et al. 2007).

There are two principal recovery efforts underway in Haida Gwaii to restore northern abalone populations. The first is the local Abalone Stewardship Program, whose goal is to restore abalone populations to a level that supports Haida subsistence harvest (Jones et al. 2004), at the scale of Haida Gwaii. The second is the National Recovery Strategy that aims to delist the species across British Columbia.

The National Strategy aims to recover abalone populations and distribution by: 1) maintaining the fisheries closures; 2) implementing a protection plan (e.g., coastal watch programs, precautionary approval of coastal development); 3) promoting communication and education around illegal poaching; 4) supporting research and rebuilding experiments; and 5) monitoring the status of the population (Fisheries and Oceans Canada 2007). Recovery activities are listed in Table 4 of the plan, along with participating agencies and organizations.

Since the species was listed in 2003, DFO has borne the majority of the costs of recovery activities related to enforcement, research and population monitoring. Outreach and public education programs and other in-kind costs towards recovery activities have been, and are expected to continue to be, incurred by Non-Governmental Organizations (NGOs) and First Nations participating in the recovery program. Local Haida Gwaii efforts to rebuild abalone populations are led by the Haida Fisheries Program and DFO in and around two Abalone Stewardship Areas in Haida Gwaii (Haida Gwaii Northern Abalone Community Action Plan 2003). Research and monitoring activities include:

1) Monitoring of abalone population and habitat conditions over time
2) Tagging and monitoring of individual abalone to determine growth rates and estimate survival and movement
3) Placement and monitoring of collector structures for juvenile abalone abundance and growth
4) Testing and monitoring of alternative rebuilding strategies to determine their potential effectiveness.

In addition, the Haida Gwaii Abalone Coast Watch monitoring network engages people and communities in active stewardship of Haida Gwaii's marine areas (Haida Gwaii Marine Stewardship Group). A Coast Watch form to help citizens report suspicious activities has been widely circulated by community partners to help bolster enforcement efforts. Since its inception, the Abalone Coast Watch Program has expanded to over 70 registered participants, including Haida Fisheries Guardians and Watchmen, Haida Gwaii Watchmen, Islanders, commercial and sport fishers, tour operators, and Gwaii Haanas staff (Haida Gwaii Marine Stewardship Group). This volunteer-based network augments the government agency resources that are currently available to monitor the coastline (Haida Gwaii Northern Abalone Community Action Plan 2003).

9. Suggested Modifications

This case will likely take a minimum of two hours, which will include phases I, II, and IV. As indicated, the case study can be extended to three hours or more if Phase III is included. If an instructor drops Phase III, the case study focuses on the interpretation and synthesis of the abalone socio-environmental challenge through various disciplinary and interdisciplinary lenses (see the table under Learning Objectives which phases meet which learning goals). This may be more appropriate for undergraduates who are less familiar with environmental management and stakeholder realities. We encourage instructors to introduce the complexities of the social and environmental trade-offs within the various management alternatives in classroom discussion.

To extend the case and spur further critical thinking around management solutions and future trade-offs, instructors may assign additional reading and reflection exercises with the Abalone Action Plan that has been published by DFO. Additionally, instructors may ask students to peruse the Abalone Stewardship Group's website and consider how various stakeholders and management players can help promote or support management solutions.

10. References

- Crim, Sunday, and Harley. 2011. "Elevated seawater CO_2 concentrations impair larval development and reduce larval survival in endangered northern abalone (Haliotis kamtschatkana)." *Journal of Experimental Marine Biology and Ecology* 400(1-2): 272-277.
- Ellis, D.W., and S. Wilson. 1981. The knowledge and usage of marine invertebrates by the Skidegate Haida people of the Queen Charlotte Islands. Queen Charlotte Islands Museum Society, Monograph Series #1. 40 pp
- Estes, J.A. and G.R. VanBlaricom. 1985. "Sea otters and shellfisheries." In *Marine mammals and fisheries*. Edited by J.R. Beddington, R.J.H. Beverton, and D.M. Lavigne. George Allen and Unwin, London. Pp. 187-235.

- Fisheries and Oceans Canada. 2007. Recovery Strategy for the Northern Abalone (Haliotis kamtschatkana) in Canada. Species at Risk Act Recovery Strategy Series. Fisheries and Oceans Canada, Vancouver. vi + 31 pp.
- Haida Gwaii Marine Stewardship Group. Accessed July, 2014. http://www.marinematters.org; Coast Watch program http://www.hgmsg.ca/coast_watch.html
- Haida Gwaii Northern Abalone Community Action Plan. Adopted September 2003, Updated March 2008.
- Haida Gwaii Traditional Knowledge Study. Excerpts from Volumes 3. August 2011. Prepared for Council of the Haida Nation by Haida Marine Traditional Knowledge Study Participants, Janet Winbourne, and Haida Oceans Technical Team, Haida Fisheries Program.
- Jones, R., N.A. Sloan, and B. DeFreitas. 2004. Prospects for northern abalone (Haliotis kamtschatkana) recovery in Haida Gwaii through community stewardship. In Making Ecosystem-Based Management Work. Munro N.W.P., J.H.M. Willison, T.B. Herman, K. Beazley, and P. Dearden, eds. Proceedings of the 5th International Conference on Science and Management of Protected Areas. Unpaginated CD-ROM. Wolfville, N.S.: Science and Management of Protected Areas Association.
- Jones, R., C. Rigg, and L. Lee. 2010. Haida Marine Planning: First Nations as a Partner in Marine Conservation. Ecology and Society 15(1):12
- Lessard, K., Campbell, A., Zhang, Z., MacDougall, L. and Hankewich, S. 2007, Recovery Potential Assessment for the northern abalone (Haliotis kamtschatkan) in Canada. Fisheries and Oceans Canada.
- Martone, R.G. and R.W. Markel, unpublished data
- Markel, R.W. 2011. Rockfish recruitment and trophic dynamics on the west coast of Vancouver Island: fishing, ocean climate and sea otters. PhD dissertation, University of British Columbia, BC, Canada.
- Micheli, F., A.O. Shelton, S.M. Bushinsky, A.L. Chiu, A.J. Haupt, K.W. Heiman, C.V. Kappel, M.C. Lynch, R.G. Martone, R.B. Dunbar, and J. Watanabe. 2008. Biological Conservation 141:1078- 1090.
- Ramsey, Heather. "The Great Abalone Theft" The Tyee. May 2007 http://thetyee.ca/News/2007/05/09/Abalone/; Ha-Shilth-Ha. "DFO Puts Abalone Project At Risk". December 2005 http://www.hashilthsa.com/archive/news/2012-08-15/dfo-puts- abalone-project-risk
- Shepherd, S.A., D. Woodby, J. M. Rumble, and M. Avalos-Borja. 2000. Microstructure, chronology and growth of the pinto abalone, Haliotis kamtschatkana, in Alaska. Journal of Shellfish Research 19:219-228.
- Sloan, N.A., and P.A. Breen. 1988. Northern abalone, Haliotis kamtschatkana, in British Columbia: Fisheries and synopsis of life history information. Canadian Special Publication of Fisheries and Aquatic Sciences 103, 46 pp.
- Sloan, N.A., and L. Dick. 2012. The Sea Otters of Haida Gwaii. Haida Gwaii Museum Press, Skidegate, BC. 190 pp.
- Sloan, N. A. 2003. Evidence of California-area abalone shell in Haida trade and culture. Canadian Journal of Archaeology 27:273–286.
- Sloan, N.A. 2004. Northern Abalone: Using an invertebrate to focus marine conservation ideas and values. Coastal Management 32:129-143.
- Szpak P, Orchard O, McKechnie I, and Grocke D. 2012. Historical ecology of late Holocene sea otters (Enhydra lutris) from northern British Columbia: isotopic and zooartchaeological perspectives. Journal of Archeological Science 39: 1553-1571.

- Wallace, S.S. 1999. Evaluating the effects of three forms of marine reserve on Northern Abalone populations in British Columbia, Canada. Conservation Biology 13(4): 882-887.
- Watson, J. 2000. The effects of sea otters (Enhydra lutris) on abalone (Haliotis spp.) populations in Campbell, A. (Editor) Workshop on rebuilding abalone populations in British Columbia. Can. Spec. Publ. Fish. Aquat. Sci. 130: 158 p.
- Watson, J. and J.A. Estes. 2011. Stability, resilience, and phase shifts in rocky subtidal communities along the west coast of Vancouver Island, Canada. Ecological Monographs 81(2):215-239.]
- Wilson, B.J. and H. Harris. 2005. Tllsda Xaaydas K'aaygang.nga: Long, Long Ago Haida Ancient Stories. In Haida Gwaii Human History and Environment from the Time of the Loon to the Time of the Iron People. Edited by D.W. Fedje and R.W. Mathewes, pp. 121-139. UBC Press, Vancouver.

11. Answer Key

Students will answer these questions on their own as homework:
1) What are 2-3 takeaways from this article?
2) Write a problem statement for the abalone management challenge.
3) Explain how confident you are in the source of information and why.
4) Identify key knowledge gaps remaining after reading this article. What additional information do you need in order to create a viable solution to the problem of abalone management in Haida Gwaii?

Potential answers for each paper/set of papers are below. Note that these are not exhaustive.

Watson, J. 2000. The effects of sea otters (*Enhydra lutris*) on abalone (*Haliotis* spp.) populations *in* Campbell, A. (*Editor*) *Workshop on rebuilding abalone populations in British Columbia.* Can. Spec. Publ. Fish. Aquat. Sci. 130: 158 p.

1) Takeaways

- Commercial abalone fisheries and sea otters appear to be mutually exclusive, but it is not clear that the exclusion of sea otters will guarantee a persistent commercial or recreational abalone fishery because overharvesting, poor or episodic recruitment, disease and predation also may prevent population recovery.
- In the absence of sea otters, abalone populations may be artificially elevated; where sea otters colonize abalone habitat, recovery targets may be too ambitious.
- Sea otters may have positive effects on abalone populations, as indicated by the co-existence of otters and abalone on evolutionary time scales. First, abalone are free spawners that require them to be in close aggregation for fertilization success. Because sea otters primarily prey on abalone that are out in the open, their presence leads abalone to aggregate in deep crevices, allowing for higher fertilization success of this free-spawning mollusk. In addition, because sea otters also prey on sea urchins, they indirectly facilitate kelp growth. This leads to much larger kelp forests in the presence of otters, providing a key food

source for abalone and leading to higher abalone growth rates and larger sized individuals. This, in turn, may lead to higher abalone population growth rates.

2) Problem Statement

Sustainable abalone harvest may not be possible in the presence of sea otters, which are recovering along the coast of British Columbia. However, sea otters may also improve long-term persistence of abalone in lower densities due to improving fertilization success and growth rates. The relatively recent extirpation and recolonization of sea otters in British Columbia limits scientific understanding of how sea otters may influence abalone populations, thus confounding our ability to design sustainable management strategies with certainty.

3) Confidence in Source of Information
   - The review covers a collection of data from western scientists, including fisheries biologists, benthic ecologists, and marine mammals biologists. Jane Watson is a credible source as she has been working to compare benthic ecosystems in areas with and without sea otters since 1987 and has gathered time series data of abalone, urchin, and seaweed abundance in areas with and without sea otters, from 1987-present. However, this is a curated list of scientific findings, and thus must be considered in the context of the western scientific perspective it presents.
   - Ecological and biological data indicate that sea otters and abalone can coexist, showing long- term persistence of abalone in the presence of sea otters in California. However, these data do not exist in BC, which presents an important gap in our understanding. It is difficult to evaluate uncertainty if the science is not place-based.

4) Key Knowledge Gaps
   - Abalone population density in the presence of sea otters compared to the absence of sea otters
   - The number of abalone that need to be in an area to maintain a viable population
   - The level of harvesting that could be sustained in the presence of sea otters
   - How might conservation limits for abalone be different for Haida food and traditional fishing compared to other fisheries due to the constitutional priority of aboriginal rights fisheries?
   - How would the return of sea otters affect abalone rebuilding? Does the presence of sea otters influence the reproductive success and viability of abalone populations (as compared to areas where they are absent)?
   - What are the legal/cultural/socio-economic ramifications of preventing or promoting sea otter recovery?
   - Is it possible to exclude sea otters from certain areas of Haida Gwaii to maintain abalone populations for harvest? How much would this cost in terms of time and money?
   - What habitat is suitable for abalone around Haida Gwaii and how does that habitat influence abalone population persistence and recovery, particularly if otters recover (i.e., percent crevice habitat; areas appropriate for kelp recovery)?

- How do other predators influence abalone recovery?

Ramsey, Heather. "The Great Abalone Theft" The Tyee. May 2007
http://thetyee.ca/News/2007/05/09/Abalone/; Ha-Shilth-Ha. "DFO Puts Abalone Project At
Risk". December 2005 http://www.hashilthsa.com/archive/news/2012-08-15/dfo-puts-abalone-
project- risk

1) Takeaways
   - Poaching of abalone continues to be the major threat affecting abalone recovery, despite the moratorium on any fishing implemented in 1990.
   - There is disagreement around how sales of farmed abalone would affect levels of poaching. Some suggest that legal sales of farmed abalone would reduce market prices and deter poaching, but SARA regulations make it necessary to track abalone that are farmed separately from those that are wild harvested. Increasing the number of legally farmed or harvested species of abalone makes it more challenging to track and enforce sales.
   - Abalone farms can also act as hatcheries which may enhance recovery of abalone
   - Enforcement is challenging in the presence of other dive fisheries, prompting some to suggest a closure of all dive fisheries in Haida Gwaii.

2) Problem Statement:
   Poaching is the major threat limiting abalone population recovery and enforcement remains difficult

3) Confidence in Source of Information
   - Journalism provides multiple perspectives on the abalone management challenge, but does not reference sufficient literature for the reader to critically evaluate the scientific underpinnings of those perspectives (e.g., assertion of market value declines are not backed up by empirical data which suggests that increased availability might increase demand).
   - This local newspaper may be trusted by the affected communities in Haida Gwaii, and thus may be an important source of information for how local residents perceive the abalone management challenge.
   - The article promotes particular kinds of information in support of abalone solutions. This may hinder confidence without clear references and statements of interest, or it may enhance confidence given that subjectivity is assumed (as compared with scientific literature, where objectivity is assumed without acknowledgement of potential author biases).

4) Key Knowledge Gaps
   - How much abalone is poached and who is doing the poaching?
   - How effective is enforcement in reducing poaching?
   - Are there other methods for deterring poaching and enforcing? How effective are community monitoring efforts?
   - How does social pressure or acceptance affect community participation in enforcing the moratorium, ignoring transgressions, or illegally poaching abalone?
   - How would abalone aquaculture sales affect market demand, poaching, and enforcement issues?

Haida Gwaii Traditional Knowledge Study. Excerpts from Volumes 3. August 2011. Prepared for Council of the Haida Nation by Haida Marine Traditional Knowledge Study Participants, Janet Winbourne, and Haida Oceans Technical Team, Haida Fisheries Program.

- a. Key Takeaways:
  - Abalone is culturally and spiritually important to the Haida. The loss of abalone within the Haida diet is deeply saddening to many peoples.
  - The Haida have great respect for abalone and shellfish and maintain a precedence of taking "only what you need."
  - The Haida's past system and norms around abalone harvest were deeply rooted in tradition and practices that would help sustain the diminishing population.
  - Traditional knowledge clearly documents abalone population decline; abalone used to be a reliable food source for the Haida. There is extensive knowledge around spatial distribution and productive areas of abalone harvest.
  - The Haida have strong critique for DFO management of the abalone fisheries; many acknowledge the challenge of poaching in limiting recovery.

- b. Problem Statement:
  The moratorium on abalone harvest has led to enormous sadness and loss in the Haida community. Loss of access to the fishery has a significant, negative impact on Haida culture.

- c. Confidence in Information Source
  - Rigorous methods were used for gathering traditional knowledge about the abalone fishery, including in-depth interviews and reviews of archival documents.
  - Direct quotes allow the reader to develop an understanding of the traditional use and value of abalone from the primary knowledge holder—the Haida people.
  - The authors acknowledge weaknesses within their study design, including the changing nature of traditional knowledge and the relative cursory nature of interviews.

- d. Key Knowledge Gaps
  - Due to the summary nature of interviews and the enormous social and political sensitivity around abalone among Haida people, information about Haida heritage sites, ecosystem interactions, and spatial distribution is limited.
  - Additional information is needed about the ecosystem dynamics, the interaction of abalone with other predators and prey (and how that influence population recovery), and viable forms of aquaculture.
  - More information is needed about how non-Haida people perceive the abalone management challenge, what losses they are suffering, and how they envision solutions.
  - Additional interviews could help identify solutions the Haida view as viable.

Sloan, N. 2003. Evidence of California-Area Abalone Shell in Haida Trade and Culture. Canadian Journal of Archeology 27(2): 273-286.

- 1) Key Takeaways:

- California-area abalone is enormously important to the Haida people and has been used in Haida art, language, and diet since the 1800s, when traders began visiting Haida Gwaii. The northern abalone shell was most likely used in Haida Gwaii before the 1800s, but has not been commonly found at archeological sites and likely held limited aesthetic value given its smaller size and paler color tone.
- Given the value of California-area abalone shell in Haida culture (e.g., adopting the shell as a family crest), it is clear coastal trade was very prevalent among indigenous peoples (before the 1800s) and with other peoples (after 1800s).
- The northern abalone has a thinner, paler shell, and thus was used infrequently in Haida culture before trade of California-area abalone was common.

2) Problem Statement:
Abalone meat and shells are highly valued by the Haida people, particularly the California-area abalone shell, which is featured in Haida art and family crests. Limited access to abalone will significantly impact Haida culture.

3) Confidence in Information Source:
- The article uses a breadth of archeological and anthropological literature to piece together the use and trade of abalone among the Haida. It also clearly states the uncertainties that remain, increasing our confidence in the study's thesis.
- The study uses radiocarbon dating to isolate the time scale of abalone trade, but fails to record the analysis methods used to reach those dates. These data are reported second-hand from other archeological literature.
- The article is heavily biased towards western scientific accounts of abalone use and trade. There are no references to Haida accounts of social use and value of abalone, calling into question the validity of the references in accurately portraying Haida culture. At the end of the article, there is a brief mention of First Nations accounts of heavy trade of the northern abalone, which would call into question the article's thesis that abalone was not as culturally significant "pre-contact" because First Nations primarily had access to the smaller and paler northern abalone species.

4) Key Knowledge Gaps:
- What are the principal threats and pressures to abalone that may impede the traditional use of its shell for cultural purposes?
- How have historical shifts in the coastal trade of abalone impacted Haida people and culture?
- How has the loss of access to northern abalone harvest impacted Haida culture? How has reduced access to California-area abalone shells impacted Haida culture?
- How do the Haida view the past and present role of non-Haida in facilitating abalone trade along the coast?
- What are Haida perspectives on the past use and trade of northern and California-area abalone? Current use and trade?
- What ecosystem dynamics, particularly involving other culturally relevant species, impact abalone populations?

Fisheries and Oceans Canada. 2007. Recovery Strategy for the Northern Abalone (Haliotis kamtschatkana) in Canada. Species at Risk Act Recovery Strategy Series. Fisheries and Oceans Canada, Vancouver. vi + 31 pp.

1) Key Takeaways
   - The goal is to reverse the decline of the northern abalone in Canada and achieve self- sustainable populations in five biogeographic regions.
   - Illegal harvest is considered to be the most significant threat to northern abalone which, coupled with abalone characteristics which make them easily harvestable, has led to an enormous decline in abalone populations over the last few decades.
   - Recovery indicators used to determine population health include various density measures and the observed mortality rate in key locations.
   - Strategies to achieve population recovery include fishery closures, a protection plan (e.g., promoting coastal watch programs), a communication campaign, research, and monitoring.

2) Problem Statement
   Illegal poaching is the greatest threat to northern abalone and federal programs must promote continued protections and increase public awareness and research if abalone populations are to recover.

3) Confidence in Source of Information
   - The Recovery Strategy was created with broad public consultation, although the degree to which particular stakeholder groups were involved is not immediately apparent.
   - The Strategy uses a wealth of scientific references and is externally reviewed by managers and academic scientists.
   - The Strategy views the abalone management challenge from a federal government and western science perspective. Given the practical and cultural realities in Haida Gwaii, uncertainty remains around whether the recovery actions proposed are culturally and behaviorally sensitive solutions (e.g., there is no consideration of social tradeoffs or what types of incentives are driving the major threats to abalone).

4) Key Knowledge Gaps
   - The Strategy does not evaluate how proposed actions will influence different human communities.
   - Additional research and understanding of how proposed actions will impact species (noted in 2.9) and ecosystem dynamics.
   - What level of population recovery is realistic, given the likely expansion of the sea otter?
   - How might the Recovery Strategy complement, enhance, or impede parallel rebuilding efforts within Haida communities?
   - What types of incentives might motivate those most likely to poach abalone to reduce their illegal harvesting practices?
   - Additional knowledge gaps, as identified within the Recovery Strategy, include data and information around larval dispersal, patch size and recruitment; species interactions (particularly sea otters as predators and sea urchins as competitors); existing or potential parasites and diseases; extent of illegal

harvest; primary threats to and identification of critical habitat (e.g., mariculture).

Haida Gwaii Northern Abalone Community Action Plan. Adopted September 2003, Updated March 2008.

1) Key Takeaways
   - Closing the federal abalone fishery in 1990 has not led to the recovery of the northern abalone population, sparking revitalized efforts to address population decline within the Haida Gwaii community.
   - The Community Action Plan emphasizes the importance of collaborative, community-based approaches to abalone management, particularly active community engagement in enforcement and stewardship.
   - The Plan emphasizes Community agreement and co-management as key principles driving Haida Gwaii community action around abalone stewardship and management.

2) Problem Statement
   Continued poaching is the greatest challenge for abalone management and current federal fisheries conservation efforts fail to adequately address this challenge. Additional enforcement capacity and ecological understanding of abalone in Haida Gwaii is needed beyond what the federal government can provide, and community-based action can help fill this gap.

3) Confidence in Source of Information
   The Plan was developed by community members and co-management partners including federal, provincial, and First Nations. It likely reflects consensus among these groups.

4) Key Knowledge Gaps
   - Do education and outreach efforts lead to improved stewardship of abalone?
   - Does the volunteer abalone watch effort reduce poaching? Are there other actions, such as the proposed monitoring of dive boats, that would further reduce poaching?
   - Does supplemental research in abalone stewardship areas enhance knowledge of abalone ecology and recovery, and can it inform management?
   - What is the minimum viable population necessary to sustain abalone in Haida Gwaii?
   - How might harvest limits be different for Haida vs. Non-Haida fishers to ensure population recovery and given the constitutional priority of aboriginal rights fisheries?
   - How might sea otters affect abalone rebuilding?

This is one example of a possible concept map depicting the abalone management challenge. There are many more creative interpretations of this complex system.
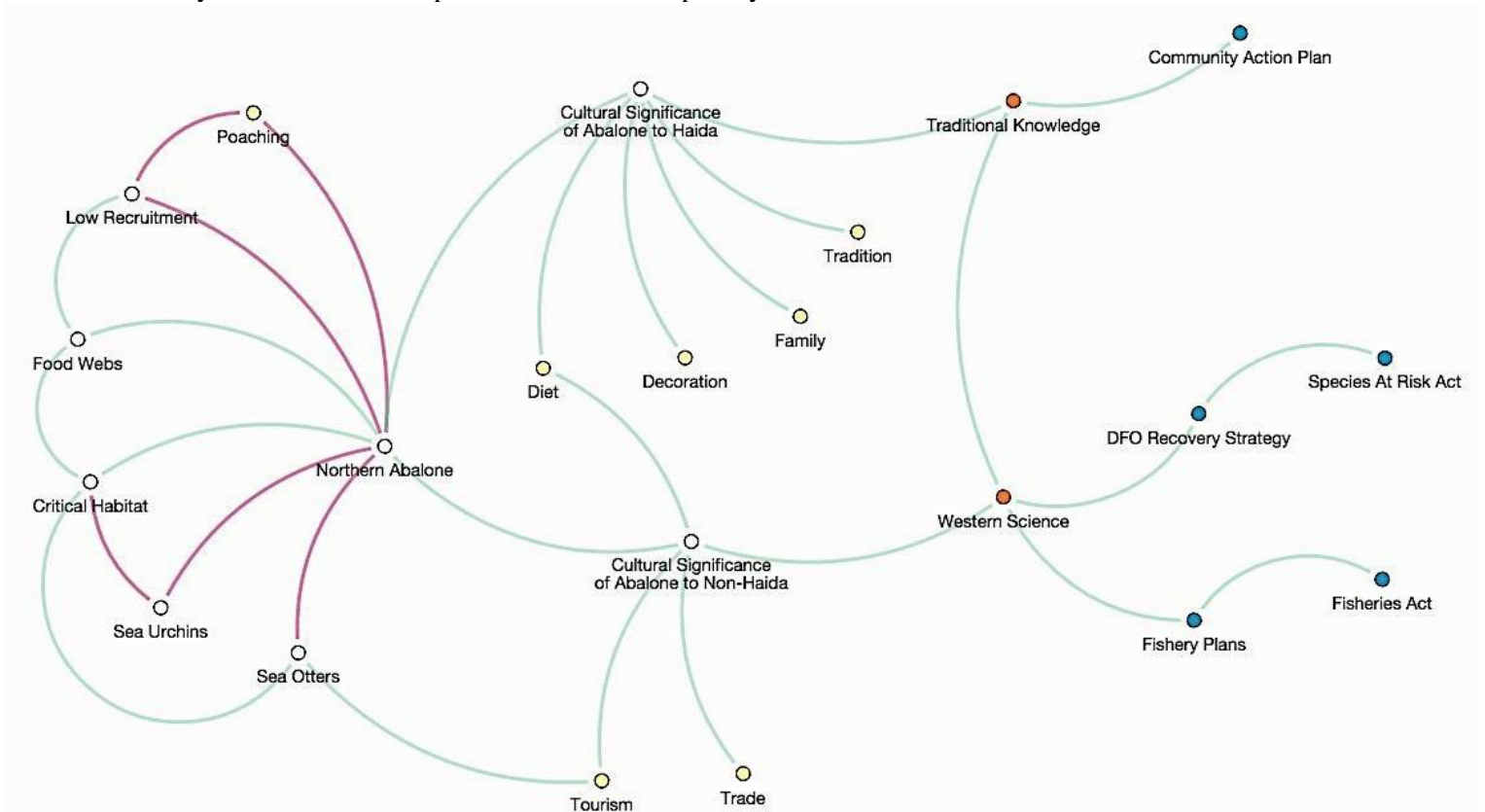
The Socio-Environmental System of the Haida Gwaii Management Challenge. *Red lines indicate negative relationships (e.g., poaching reduces abalone populations) and green lines indicate positive relationships (e.g., abalone use in Haida tradition contributes to the cultural significance of abalone within Haida culture). White dots indicate ecosystem components, yellow dots indicate use and non- use values of abalone, orange dots are 'ways of knowing', and blue dots are management efforts or laws.*

12. Assessment

Formative Assessment
1) Instructors will receive student homework assignments before the class begins. Suggested assessment criteria:
    a. Allocate 1 point for each homework question the students answer (see answer key above) (4 points total). Consider the following learning objectives:
        i. Students will be able to identify management-relevant components of abalone ecology and ecosystem dynamics, Haida culture and worldview, and the social history and significance of abalone for Haida and non-Haida.
        ii. Students will translate knowledge from one scientific, social, economic, or political perspective to another.
        iii. Students will read and interpret information from various, credible sources, and evaluate how those sources of knowledge can be used in decision making.

2) Students will share key takeaways and reflections on their homework readings with each other. This presents an opportunity for peers to provide critical feedback around students' understanding, synthesis, and communication of case study content.
3) Instructors will observe student discussions in small groups during the discussions that close each Phase (I – IV). Suggested informal assessment criteria for small group discussions are included under "Assessment Goals" above.

Summative Evaluation
Each student will complete a small handout with these questions at the end of the case study.
   a. Handout questions:
      i. Socio-environmental problems have been called 'wicked' because they are so complex. Why is it so difficult to resolve these issues?
      ii. You were exposed to data from several different disciplines. How did using different datasets affect your perception of the problem and the possible solutions? Why is it relevant to assess different types of data when considering different environmental policy and management options?
      iii. We included information from a wide range of data sources in our fact sheets. Which types of information sources are most useful/which do you trust the most? Which are least useful?
      iv. Look at the two concept maps you created at the beginning and end of this case study. What changed? What elements of your second map reflect a greater understanding and/or synthesis of the abalone socio-environmental challenge?
      v. What did you find to be the strengths of this case study?
      vi. What would you change to improve your learning experience during this case study?
   b. Suggested assessment criteria:
      For the first four questions, 1 point will be given if the answer meets the learning objectives below or 0 points if it does not meet the learning objectives), based on the quality of the answer (4 points total)(rubric below).

      i. Students will reflect on their normative understanding of this socio-environmental case study and how that perspective may conflict with various stakeholders' livelihoods and beliefs.
      ii. Students will have greater comfort with the scientific and socio-cultural complexities of socio-environmental problems.
      iii. Students will understand the need for multiple perspectives and ways of knowing in order to identify trade-offs associated with viable solutions in this and other socio-environmental challenges.
      iv. Students will engage in open dialogue with peers and experts around the challenges and opportunities of interdisciplinary collaboration

   c. Example rubric:
      • Socio-environmental problems have been called 'wicked' because they are so complex. Why is it so difficult to resolve these issues?
         o Answers could speak to how socio-environmental problems emerge in students' own lives, how such problems often contain social and environmental trade-offs, and how differing perspectives complicate decision making.

- *Sample answer:* Socio-environmental problems require an understanding of how human and ecological communities interact. Therefore solutions must directly address complex feedbacks and incorporate the often immensely diverse perspectives of the people that depend on natural resources. In this case study, the ethical and sustainable management solution for abalone is clouded by scientific uncertainty, conflicting social preferences, and legacies of cultural divides and power inequities—challenges that often complicate socio- environmental issues.

- You were exposed to data from several different disciplines. How did using different datasets affect your perception of the problem and the possible solutions? Why is it relevant to assess different types of data when considering different environmental policy and management options?
  - Answers could reflect on how particular data contribute to various perspectives and how various sources are limited by their methodologies or presentation. Students could reflect on the importance of various data for deciphering management options and the challenges of translating and integrating different ways of knowing into a decision that will meet many stakeholders' needs.
  - *Sample answer:* My article only gave me one lens to understand the abalone management challenge. It provided me with valuable information, but layering other dimensions—whether social or ecological—was critical for understanding the real complexity of the case and thus, understand the solution landscape. It made me realize that no matter how many perspectives I uncover or data I collect, there is no "right" answer. It is a process of continuing to unravel what we know about how ecosystems might respond and change, and what we know about human history and interests, and from that process continue to negotiate the challenging space of equitable resource use.

- We included information from a wide range of data sources in our fact sheets. Which types of information sources are most useful/which do you trust the most? Which are least useful?
  - Answer will depend on the student. Answers could reflect on how particular data contribute to various perspectives and how various sources are limited by their methodologies or presentation. Students could reflect on why they trust various information sources due to their own training and how their biases has influenced their interpretation of case material.

- Look at the two concept maps you created at the beginning and end of this case study. What changed? What elements of your second map reflect a greater understanding and/or synthesis of the abalone socio-environmental challenge?
  - Answer will depend on the student. Students could highlight where they have added or subtracted key interactions, particularly between social and ecological components of the system. Students could reflect on how the map has changed

based on additional perspectives gleaned or limitations in their initial article.

2) Student concept maps depicting their understanding of the system at the beginning (in small groups) and end of the class (individually).
   a. Learning Objectives
      i. Students will link ecological dynamics of abalone management and the social and cultural dimensions of abalone management together through individual and group conceptual models and reflection.
      ii. Students will understand the key issues and feedbacks between natural resources, users of those resources, and the managers and decisionmakers that govern them.
   b. Suggested assessment criteria (**4 points total**):
      i. Linkages: Did the student draw linkages across disciplinary components of the system? (1 point)
      ii. Thinking and ideas: Did the student demonstrate an understanding of system components (1 point), and an evolution of that understanding over the case study exercise (1 point)?
      iii. Aesthetics: Did the student organize the map in an effective and understandable format? Is it aesthetically pleasing? (1 point)

Instructors may evaluate, on average, how many of the learning objectives students meet by quantifying the 12 points identified above. Instructors can use questions 5 and 6 of the summative evaluation to identify how the case study can be improved to meet a greater number of learning objectives (particularly for students that score below six overall).

13. Acknowledgments