Perceptions of change in Puget Sound:

Documenting historical trends in abundance of marine species using local knowledge

Summary of research results

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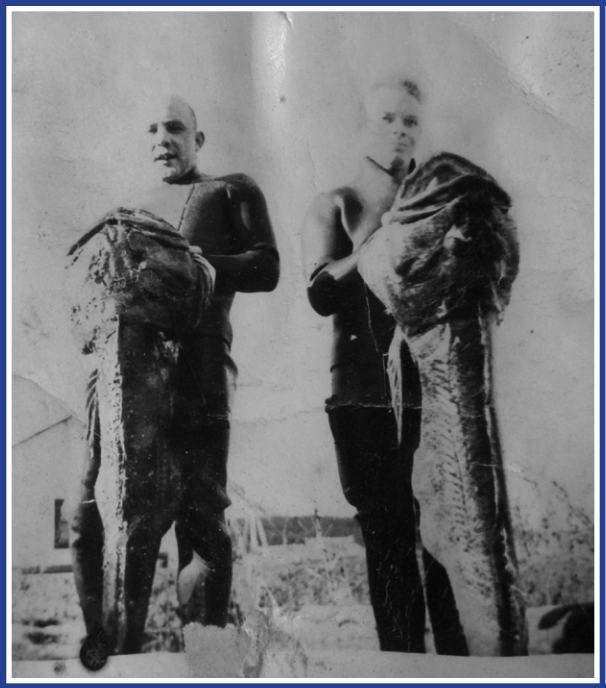

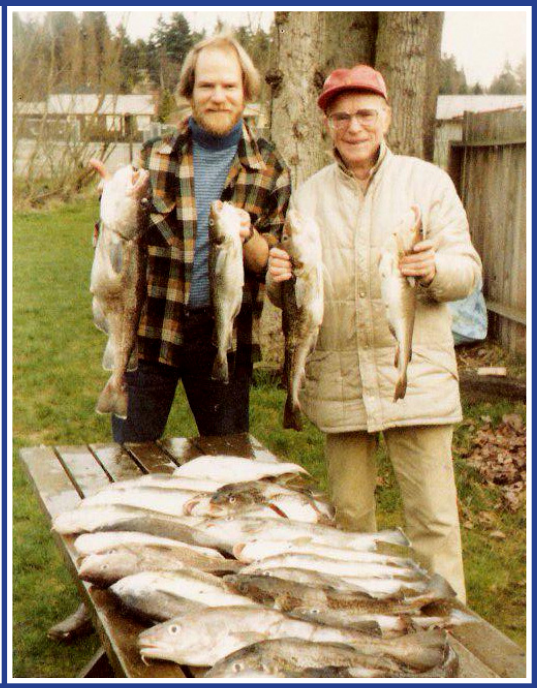

Photos courtesy of: Roger Loring Frank Haw Mark Pedersen

The Backstory

In 2009 and 2010, I interviewed 101 fishers, divers, and researchers around Puget Sound to document their observations of abundance changes in fish, invertebrate, and marine mammal populations since the 1940s. I began this project while working as a research associate at the University of Washington in collaboration with Dr. Phil Levin, an ecologist, and Dr. Karma Norman, an anthropologist, at the Northwest Fisheries Science Center in Seattle.

I had just finished my Ph.D. in Fisheries at the University of Washington in summer 2009 and was eager to begin the next stage of my career. I had spent the last 5 years studying the role of lingcod as a top predator in kelp forest ecosystems. A large component of my work involved examining lingcod stomach contents to document their diets. I would catch lingcod using hook and line, give them a mild sedative, and flush their most recent meal into a sieve using a hand pump. Over the years, my field assistants and I caught more than 1,100 lingcod and 1,100 other fish, including rockfish. What we learned contributed to a better understanding of lingcod ecology—what they eat, how they behave, and the impact they have on prey populations. Along with the data, we racked up a bounty of fishing stories that sustained me through the long days of data analysis ahead.

During my days in the field, I not only developed a passion for fishing, but also gained a deeper understanding of nature that comes from time spent on the water. I saw a need for a historical perspective on the rapidly changing Puget Sound ecosystem and wondered if there was a way to document the local knowledge that fishers and others had gleaned from a lifetime of experience on the water. If so, could this knowledge be used alongside scientific data to improve our collective understanding of changes in fish populations? This question became the genesis of my study and I spent the next two years delving into the rich history of Puget Sound's fisheries and fisherfolk. This newsletter briefly summarizes major results of the research, which is also detailed in scholarly journal articles (see *References*, below, for full citations). I am happy to provide those publications in electronic format to anyone who requests them.

In 2011, I moved to Juneau, Alaska, where I am now an Assistant Professor of Fisheries at the University of Alaska Fairbanks. Despite a new focus on the ecology and human dimensions of Alaska's fisheries, I will always have a deep connection to Puget Sound and look forward to future work there.

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Historical Changes in the Puget Sound Ecosystem

The Puget Sound ecosystem has undergone dramatic changes over recent decades. The human population has increased nearly 8-fold over the last 100 years in the Puget Sound region[1]. Coastal development, fishing, pollution, and other pressures have led to population declines of many marine species.

Our research was aimed at understanding long-term changes in populations of marine mammals, invertebrates, and fishes, with a particular focus on rockfish. Rockfish are a diverse group of very long-lived bottomfish species, some achieving maximum ages of up to 205 years[2]. True to their name, rockfish have a strong affinity for rock and kelp forest habitats. Most species tend to stay close to home, some with home ranges as small as 10 square meters[2]. Because rockfish mature slowly and show limited movement, they are particularly vulnerable to fishing. Once an area is fished out, it can take some time to replenish it with new recruits.

Rockfish have shown declines in abundance and body size along the entire west coast over the past several decades. In 2010, three species of rockfish in Puget Sound were listed for federal protection under the Endangered Species Act (ESA). This marked the first time that rockfish were listed as endangered or threatened under the ESA anywhere in their geographic range. Currently, targeted harvest and retention of rockfish is not allowed in Washington marine waters east of Marine Area 5 (approximately 123°49.6' W)[3]. Fishing for lingcod and other bottomfish species is limited to 120 feet or shallower to minimize mortality of incidentally caught rockfish.

Developing a recovery plan for rockfish requires historical information about trends in rockfish populations. What changes have rockfish populations undergone in Puget Sound? If rockfish have declined, how great has their reduction been and when did it occur? What did rockfish populations look like historically?

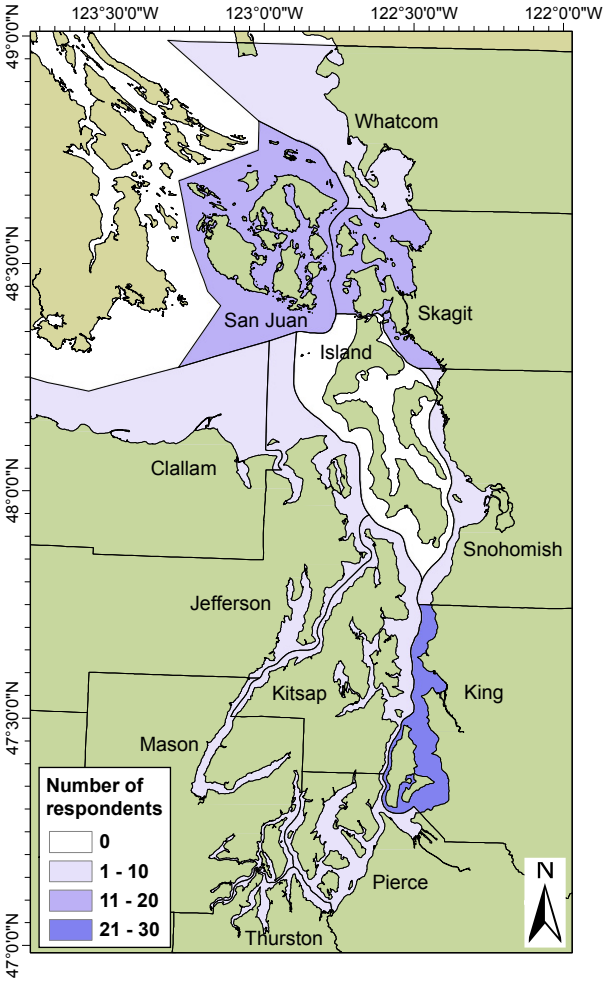
Unfortunately, for rockfish and many other Puget Sound species there is little or no historical data that can be used to answer these questions. Abundance, distribution, size structure, and catch records are lacking for many rockfishes and available data are coarsely aggregated for multiple species or locations, limiting their use for quantitative assessment of rockfish stocks[4]. This information gap presents a challenge for the managers who are tasked with setting goals for rockfish recovery. This problem motivated me to develop an approach for reconstructing historical trends in fish abundance using local knowledge of experienced fishers, divers, and researchers.

Photo by Frank Haw

Terrel Poage of Tumwater, Washington, with a yelloweye rockfish (left) and a bocaccio (right) that he caught in Neah Bay, circa late-1970s. Yelloweye rockfish and canary rockfish are now listed as threatened and bocaccio as endangered in Puget Sound.

Recording Local Knowledge from Interviews

The use of local knowledge to inform science has gained traction over the past decade. In the scientific literature, the knowledge and insights people have acquired through extensive observation of an area or species is commonly referred to as local ecological knowledge, or LEK[5]. Because LEK is filtered through the memories and experiences of individuals, it not only reflects people's observations of nature but also their personal relationship to the natural world. Differences in the way individuals observe or 'sample' the ecosystem (for example, fishing or diving) and the timeframes over which those observations have been made can translate to differences in people's perceptions of change. A primary goal of my research was, therefore, to understand how variation in people's perceptions of Puget Sound species diversity and abundance could affect the way LEK is interpreted to inform our understanding of historical changes in rockfish populations. In the sections that follow, I describe two parts of this study—one that examined people's perceptions of biological diversity and one that documented people's perceptions of abundance changes for rockfish and other species.



Interview Participants

Over a one year period, I conducted in-person interviews with 101 individuals who were knowledgeable about rockfish and had at least ten years of fishing, diving, or research experience in Puget Sound. I made initial contacts with university and agency scientists, recreational fishing and diving club members, and fisheries coordinators for the Northwest Indian Tribes to disseminate information about the study and recruit participants. I asked each person I interviewed to recommend other potential study participants. This sampling approach, termed snowball sampling, is common in the social sciences and is an effective way of identifying a large number of people with specific knowledge and expertise[6].

Interview respondents had a wide range of experience, including commercial and recreational fishing, charter operation, commercial and recreational diving, research, environmental journalism, and fishing- or diving-related entrepreneurship. A majority of respondents (84%) indicated that they had experience in two or more of the following major activity types: 1) recreational fishing, 2) commercial fishing, 3) charter operation, 4) diving, and 5) research. Each person's principal activity type was determined based on their reported average number of days per year and total years of participation in each of these activities. Recreational fishing was the principal activity type for the majority of respondents (55%), followed by recreational diving (16%), research (14%), and commercial fishing (10%).

Respondents also provided basic demographic information, including age, race, and city or town of residence. Respondents ranged from 24 to 90 years of age, with a median age of 60. I interviewed people residing in 12 counties bordering Puget Sound (above).

Part 1: Perceptions of Biological Diversity

In science, plants and animals are grouped, named, and classified according to their evolutionary history. Closely related creatures are clustered together more tightly than they are to their distant relatives. Students are routinely taught this scientific classification system, or taxonomy, in their biology courses as a useful way to study relationships among organisms. However, scientific taxonomies may not be the most intuitive way of organizing nature in a practical sense. People might classify plants and animals based on their cultural or economic value, habitat associations, or size and coloration. For example, as an ecologist, I often think about fish in terms of their behaviors and habitat associations: rockfish and lingcod dwell in rocky reefs near the seafloor, while salmon and herring tend to live a more open-water lifestyle. Though the process is subconscious, I am inherently forming my own taxonomy that reflects my specific knowledge about the ecology of these species. My personal approach to naming, identifying, and grouping species is termed a "folk taxonomy" by anthropologists and may be very different from the scientific taxonomy I was taught in school.

People tend to have specific names for animals that they are familiar with. Even very similar looking animals are easy to distinguish if someone has spent time observing them. Pictured below are two common mammals that we all know well: a dog and a cat. Distinguishing between these animals is a simple task for most people, even though they both have orange fur, pointy ears, four legs, and long, fluffy tails. The problem of species identification is much more difficult in the marine environment, where most fish and other organisms are hidden from our view, deep under the water where anglers can't see them or in habitats that are inaccessible to divers. Take rockfish, for example. Some species, like yelloweye rockfish and canary rockfish, live in deep water and are rare in Puget Sound. They also look remarkably similar. Even experienced fishers and divers may have a difficult time distinguishing between yelloweye and canary rockfish.

Dog | Cat | Canary rockfish | Yelloweye rockfish

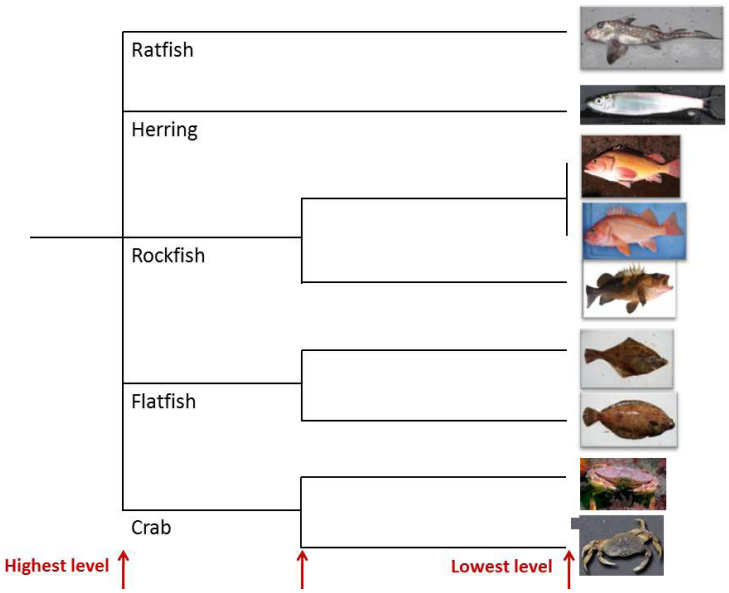
For many years, the Washington Department of Fish and Wildlife did not identify these species separately in commercial and recreational fishery harvest data, referring to both as "red rockfish." This grouping limits the usefulness of harvest data for estimating the abundance of each species, information that is important for rockfish assessment and recovery planning. Additionally, most recreational catch data is self-reported, so understanding how people identify (or misidentify) fish species is necessary for evaluating the accuracy of the reported catch.

In Part 1 of the study, we asked three major questions:

1) Are the folk taxonomies different from a scientific taxonomy?
2) How similar are folk taxonomies of fishers, divers, and researchers?
3) Are people consistent in the ways that they identify and name Puget Sound species?

Constructing the folk taxonomies

I used a grouping and identification exercise, called "pile sorting," to document respondents' folk taxonomies[6]. Each respondent was given 46 color photos of marine mammal, fish, and invertebrate species in Puget Sound and asked to "group these according to what belongs together using any criteria you wish." The sorting task was repeated for each group individually until no further subdivisions could be made. At this final sorting step, the respondent was asked to identify each organism by name (if any). Using the pile sort results, I was able to construct a folk taxonomy for each respondent. I used a statistical method called multivariate ordination to compare folk taxonomies with a scientific taxonomy and among different groups of respondents.



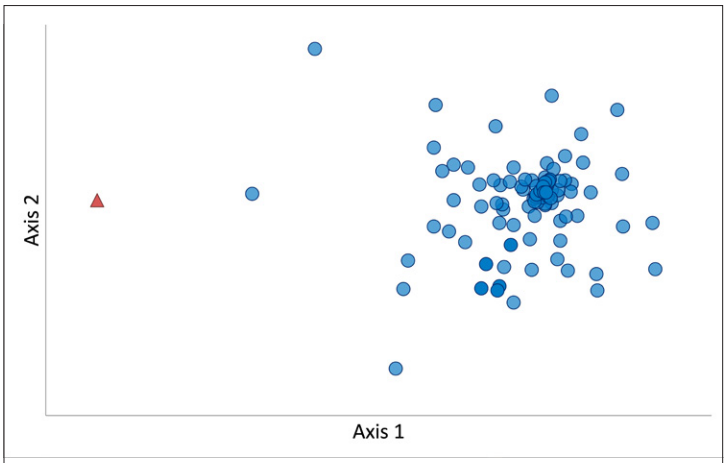
An example of a folk taxonomy with 9 species. The respondent first sorted the pictures into five broad groupings ("highest level"), then subdivided some of those into smaller groups, and finally identified individual fish and invertebrates by name ("lowest level"). In this example, yelloweye and canary rockfish were not distinguished from each other and called by the same name.

Asking respondents what their names are for each species was useful from a research standpoint because it ensured that I was on the same page as the person I was interviewing. For example, a "yelloweye rockfish" to me might be a "red snapper" to someone else. By knowing that, I could adapt my own names to those of the respondent to improve our communication during the interview.

Are the folk taxonomies different from a scientific taxonomy?

Yes! Our analysis showed that people grouped and identified animals in a way that was distinct from a scientific taxonomy. Notably, this was true even for scientists.

In the plot below, each point represents one person's taxonomy. The distance of the points from each other reflects how similar the taxonomies are to each other. Points (taxonomies) that are closer together are more similar to each other than points that are further apart. The scientific taxonomy was more complex than the folk taxonomies. It was organized into seven levels of grouping, compared to 4-6 levels for the folk taxonomies. Certain species were also grouped differently in the scientific taxonomy compared to the folk taxonomies. As an example, four pelagic (open-water) fish species—Pacific herring, Northern anchovy, Pacific sand lance, and surf smelt—belong to different scientific family groupings and are, therefore, split into different branches of the scientific taxonomy. In contrast, these same four species were often grouped together by respondents into one cluster and identified as "forage fish" or "bait fish." This is a good example of how people's knowledge of these species as small schooling fish that provide food for other organisms and serve as excellent bait for fishing is reflected in their folk taxonomies.



This plot shows differences between folk taxonomies (blue circles) and a scientific taxonomy (red triangle). A detailed explanation is given above.

Photo courtesy of Ray Buckley

Fisheries scientists Frank Haw and Ray Buckley show off their rockfish catch near Gedney Island in the early 1980s.

How similar are folk taxonomies of fishers, divers, and researchers?

Many folk taxonomies were similar to each other, as seen by the cluster of overlapping points in the middle of the plot. However, you will notice that a number of points are spread out from this central cluster, showing that there was a wide variety in folk taxonomy structure. This variation might be due to differences in the ways that people observe or 'sample' the environment. My analysis showed that there were significant differences in folk taxonomies among respondent groups with different types of experience in the marine environment and that the biggest distinction was between fishers and divers. For example, divers tended to lump the five salmon species together into one salmon group, whereas fishers identified the salmon species separately and provided specific names for each. When you consider the differences in how fishers and divers are observing fish, this makes sense. Divers seldom see salmon underwater and, if they do, it is often a fleeting event. On the other hand, fishers often target salmon and, as a result, have more of an opportunity to see them up close. In addition, fishers have to be aware of the differences among species to comply with fishing regulations.

Are people consistent in the ways that they identify and name Puget Sound species?

A large majority of respondents (93%) did not distinguish between at least 2 species. In the example folk taxonomy shown on the previous page, the respondent did not distinguish between yelloweye rockfish and canary rockfish, calling them both "red snapper." On average, respondents had between 5 and 6 groups of at least 3 species that they lumped together. The species that were the most commonly aggregated—grouped together by more than half of the respondents—included rockfishes and flatfishes. The species that stood out as the most distinctive—grouped by fewer than 10% of respondents—were spiny dogfish, ratfish, Dungeness crab, red rock crab, Steller sea lions, and harbor seals.

"We were under the impression—probably the wrong impression—that the different colors [of rockfish] were reflective of the bottom structure. It wasn't a different species, it was a different colored bottom structure that they had adapted to, and so identifying these to different species never really held that much interest for some reason. They were all rockfish. If they had big spines on their back, they were rockfish."

- Interview Respondent

Summary and conclusions

In part 1 of the study, we found that there were significant differences between folk taxonomies and a scientific taxonomy. That is, people perceive biological diversity—the family tree of life on earth—differently from what is dictated in scientific textbooks. People's views of how animals are grouped and classified are shaped by the types of experience they have in the marine environment. Whether someone dives, fishes, or conducts research determines his or her familiarity with different species and opportunities for observing them. **These results are important because they remind us that our experiences in the natural world shape the way we view nature—the way it is organized, its use and value, and our relationship to it.**

The species that were the most difficult to identify—rockfishes and flatfishes—were often grouped together by experienced anglers, divers, and researchers. Why does this matter? First, this is important from a management standpoint. If anglers are asked to report the species of rockfish that they catch incidentally when targeting other fish, like salmon and lingcod, it is important to provide information to anglers to help them identify rockfish. The Washington Department of Fish and Wildlife recently updated the sportfishing regulations with pictures and more detailed descriptions of rockfish to aid anglers in identification.

Beyond species identification, understanding people's folk taxonomies is also important for interpreting LEK about fish abundance changes. As an illustration, we summarized abundance data for two rockfish species based on how they were classified in folk taxonomies. Greenstriped rockfish and bocaccio were viewed as the same species by 40% of respondents. Yet, their populations have undergone very different trajectories along the U.S. west coast: greenstriped rockfish increased 7.9% from 1977 to 2001, while bocaccio declined 16.9% over the same period [7]. To respondents who did not differentiate between the two species (i.e., they are both "rockfish"), the decline of bocaccio would be masked by an increase in the much more abundant greenstriped rockfish.

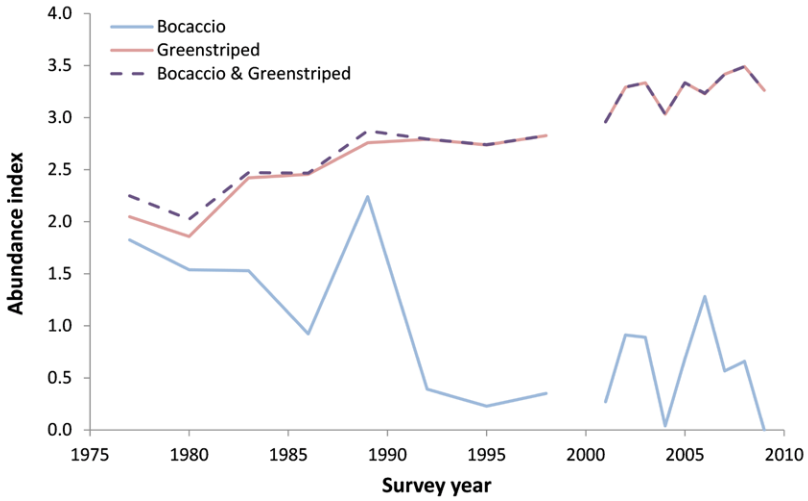


Photo by Dan Kamikawa

Greenstriped rockfish

Photo by Matt Barnhart

Bocaccio

These individuals might conclude that extinction risk to rockfish is quite low, in contrast to those who perceived bocaccio as a distinct species. Thus, stakeholders may perceive risk to rockfish in different ways because they are using fundamentally different information to assess it. This could lead to divergent beliefs about the need for conservation of particular species. We often think about conflict in natural resource management as emerging from different goals and values among stakeholders and managers. Yet, disagreement among stakeholders in their perceptions of extinction risk may not only reflect differing values, but also fundamental differences in how people view biological diversity.

Part 2: Perceptions of Species Abundance Changes

In Part 2 of the study, we asked the following questions:

1) What changes in fish populations have people observed over time?
2) Do abundance trends from interviews mirror current scientific understanding?
3) Do people's observations agree?
4) Is variation in people's perception of abundance trends related to their expertise or age?

Species common name	Species scientific name
Black rockfish	*Sebastes melanops*
Bocaccio	*S. paucispinis*
Brown rockfish	*S. auriculatus*
Canary rockfish	*S. pinniger*
Comb jelly	*Mnemiopsis leidyi*
Copper rockfish	*S. caurinus*
Dungeness crab	*Metacarcinus magister*
English sole	*Parophrys vetulus*
Harbor seal	*Phoca vitulina*
Lingcod	*Ophiodon elongatus*
Lion's mane jelly	*Cyanea capillata*
Moon jelly	*Aurelia aurita*
Pacific cod	*Gadus macrocephalus*
Pacific hake	*Merluccius productus*
Pacific halibut	*Hippoglossus stenolepis*
Pacific herring	*Clupea pallasii*
Pacific sanddab	*Citharichthys sordidus*
Quillback rockfish	*S. maliger*
Sablefish	*Anoplopoma fimbria*
Spiny dogfish	*Squalus acanthias*
Spotted ratfish	*Hydrolagus colliei*
Yelloweye rockfish	*S. ruberrimus*

Documenting abundance trends

As a component of the interviews, I asked people about their observations of changes in the abundance of 22 Puget Sound species (right). For each species, I asked the respondent to indicate the abundance level in each decade that he or she had fished for or observed that species. The respondent was asked to select from seven abundance categories: very high, high, medium-high, medium, medium-low, low, and very low. The example below shows two respondents' observations for yelloweye rockfish. The responses shown in red were provided by someone who had been fishing since the 1940s, while the responses in blue are from a person who had fished since the 1970s.

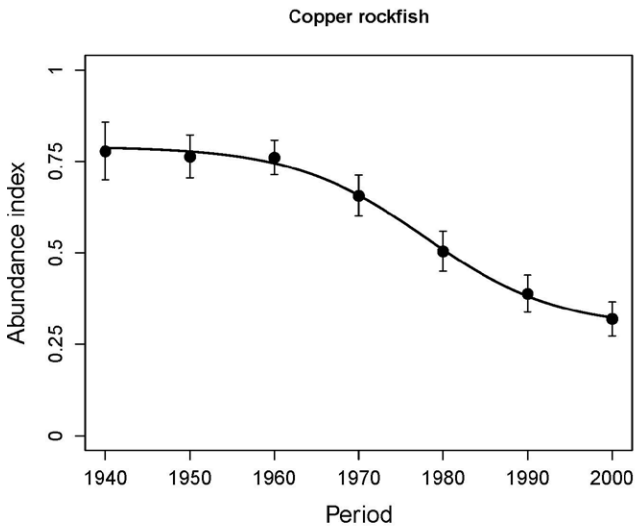
Indicate abundance level for each decade

1940s	1950s	1960s	1970s	1980s	1990s	2000s
Very High	Very High	Very High	Very High	Very High	Very High	Very High
High	High	High	High	High	High	High
Med-High	Med-High	Med-High	Med-High	Med-High	Med-High	Med-High
Medium	Medium	Medium	Medium	Medium	Medium	Medium
Med-Low	Med-Low	Med-Low	Med-Low	Med-Low	Med-Low	Med-Low
Low	Low	Low	Low	Low	Low	Low
Very Low	Very Low	Very Low	Very Low	Very Low	Very Low	Very Low

Photo by Rick Hibpshman

Yelloweye rockfish

I converted these categories into numerical scores and averaged all of the respondents' scores for each decade. I showed the trends using smoothed curves that I estimated using a statistical approach called non-linear regression. Here is the resulting abundance trend for copper rockfish:



The points are the average abundance scores and the vertical lines show the variation around those averages (two standard errors, statistically speaking).

What changes in fish populations have people observed over time?

People observed declines in abundance for many species over the past 70 years. The greatest declines were observed for sablefish, hake, Pacific cod, herring, and rockfishes. The abundance trends from interviews suggest that populations of seven rockfish species in Puget Sound have been in decline since at least the 1960s. Less marked declines were seen for spiny dogfish and small flatfish, like rock sole. Respondents did not observe much change in the abundance of jellyfish, Dungeness crab, halibut, or ratfish. However, a number of respondents noted that the jellies and Dungeness crabs tend to fluctuate in abundance from year to year, so reporting changes on a 10-year time scale was difficult. Lingcod were observed to increase in abundance from the 1940s to the 1950s, followed by a decline through the 1990s and subsequent increase in the 2000s. Overall, the only continuous increase was reported for harbor seals, which grew in abundance following protection under the Marine Mammal Protection Act of 1972.

Canary and yelloweye rockfish, the two species listed as threatened under the ESA, were perceived to be at a lower abundance across all time periods by both fishers and researchers, compared with black, copper, and quillback rockfish. There was also greater uncertainty in the abundance levels of canary and yelloweye before the 1960s compared to other species. This may be due to the rarity of these rockfish species in the environment and, therefore, limited opportunities for respondents to observe them. For infrequently encountered species, it was difficult for respondents to recall and synthesize their observations into abundance categories, particularly for early periods. A number of respondents noted that they were unsure whether they had caught a bocaccio during the earlier periods of their fishing history, but were increasingly confident that they had not seen one in the later decades, describing them as "uncommon," "infrequent," or "nonexistent."

Photo courtesy of Jeremy Nash

"We used to live off the land. You could go up and hunt rabbit, fish, dig clams, get oysters. You could live off the land. You didn't have to take anything with you other than if you needed something like flour to cook the fish in. Back in the old days you could catch 14 rockcod for dinner."

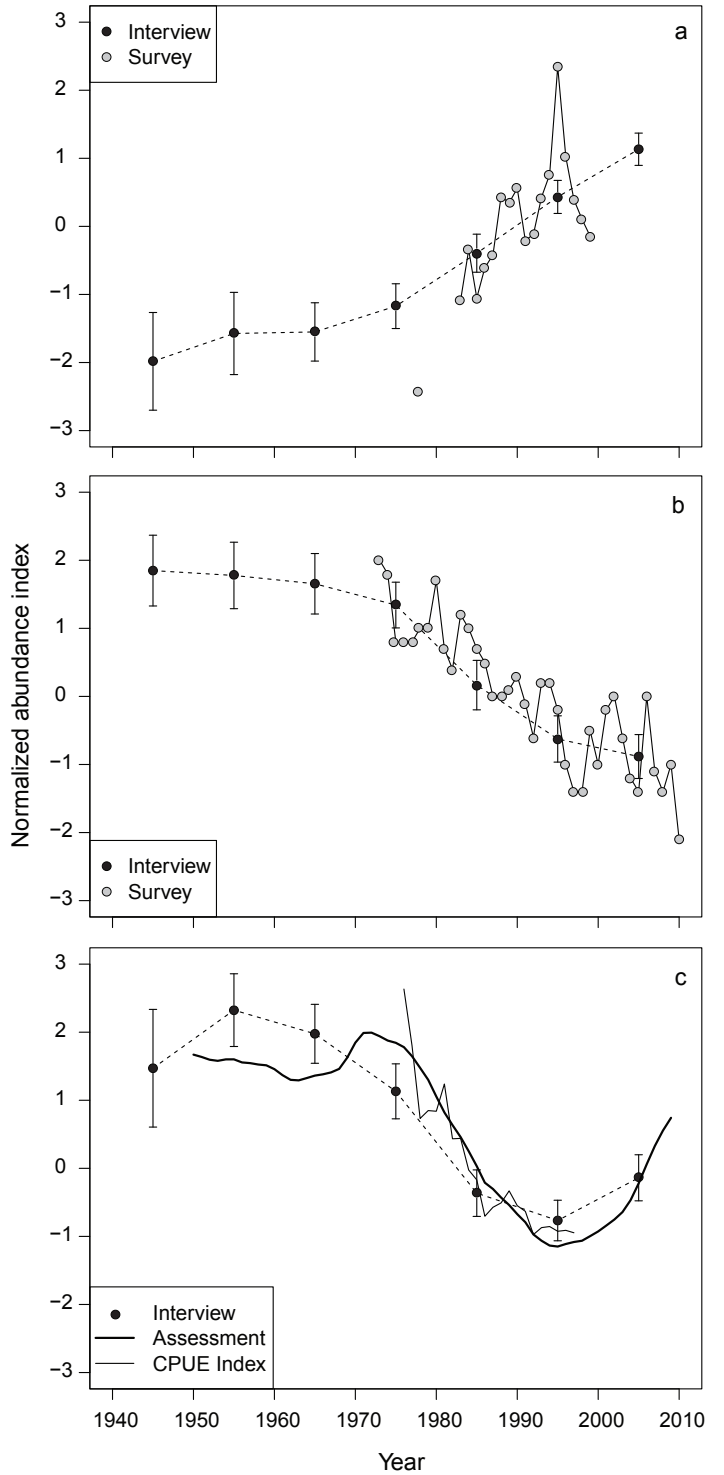
- Interview Respondent

Do abundance trends from interviews mirror current scientific understanding?

One of the questions often asked about LEK is: does the information provided agree with scientific observations? In this study, we compared abundance scores from interviews with scientific survey data to assess agreement between LEK and scientific observations for three species with available long-term data: harbor seals, Pacific herring, and lingcod. Although the observations from interviews do not capture the year to year variability in abundance in the same way that annual survey data do, the overall trends are very similar between LEK and scientific observations (right). When two or more sources of information that were collected in different ways—such as LEK and scientific observations—show agreement with each other, we have improved confidence that they both reflect true patterns in nature.

Do people's observations agree?

In general, there was strong agreement in people's observations of long-term abundance changes for Puget Sound species. However, some variation in abundance scores was still evident, particularly for certain species or time periods. People's perceptions of nature can be influenced by their "information environments," or the type of specific ecological information a person has access to, and how, when, and where he or she has acquired it[8]. Just as people's folk taxonomies were influenced by the way in which they observed the marine environment, people's perceptions of abundance changes could be affected by their observation methods and the time frames over which those observations have been made. I tested this by comparing rockfish abundance trends for respondent groups with different types of expertise and among people of different ages.



Comparison of abundance trends from interviews (black points) and scientific data sources for (a) harbor seals, (b) Pacific herring, and (c) lingcod.

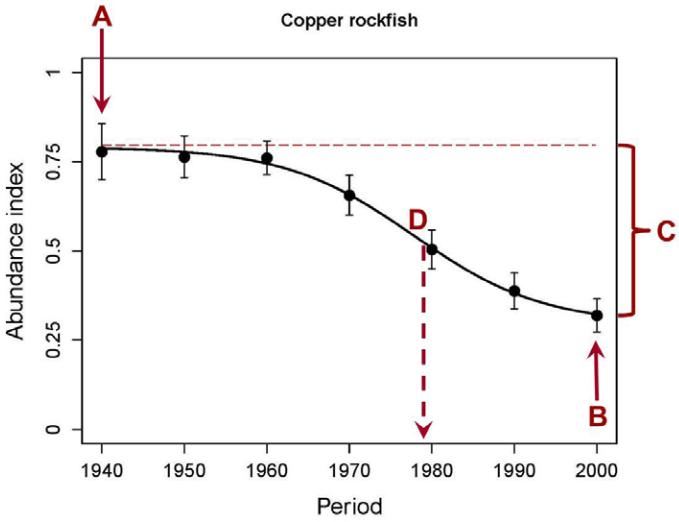
Is variation in people's perception of abundance trends related to their age?

To understand generational differences in people's perceptions of fish abundance, I performed a statistical analysis that estimated the probability of reporting low rockfish abundance for different respondent age groups. Older respondents were much more likely to report low rockfish abundance compared to younger respondents across all time periods. This phenomenon is known as the "shifting baseline syndrome," a term coined by fisheries scientist Daniel Pauly in the 1990s[9]. Pauly suggested that in the absence of long-term data, people view the condition of a fish population observed at the start of their lifetimes as the historical baseline. From one generation to the next, people's perception of this baseline "shifts" to a lower and lower abundance as a fish population declines. The result is that we may not notice gradual depletion of fish populations, because our view of what a high abundance of rockfish looks like changes with each generation. Our results show the importance of documenting historical change in fish populations and accounting for age when interpreting LEK.

Photo courtesy of Ray Buckley

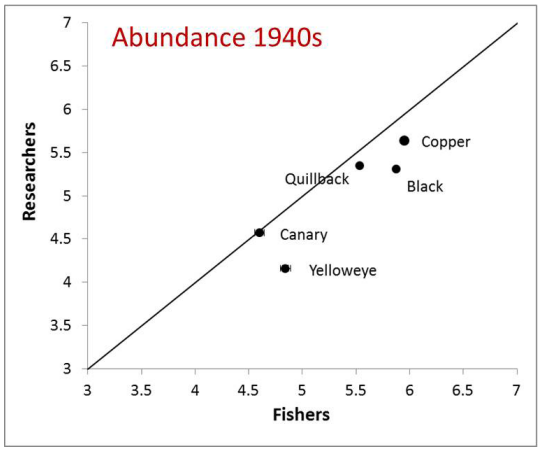
Is variation in people's perception of abundance trends related to their expertise?

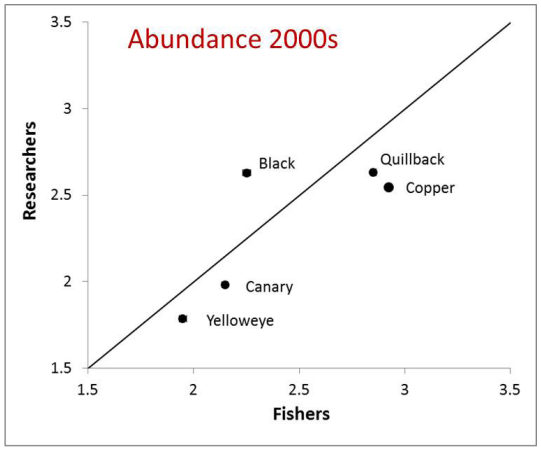
To address this question, I compared observations for recreational fishers and researchers. I hypothesized that fishermen and scientists might draw their conclusions about rockfish abundance changes based on different types or sources of information, resulting in differences in their reported abundance trends for rockfish. For each rockfish species, I compared four attributes of fishers' and researchers' abundance curves:



In the plot above, A is the initial abundance index (1940s), B is the final abundance index (2000s), C is the total change from the 1940s to the 2000s, and D is the midpoint of the decline.

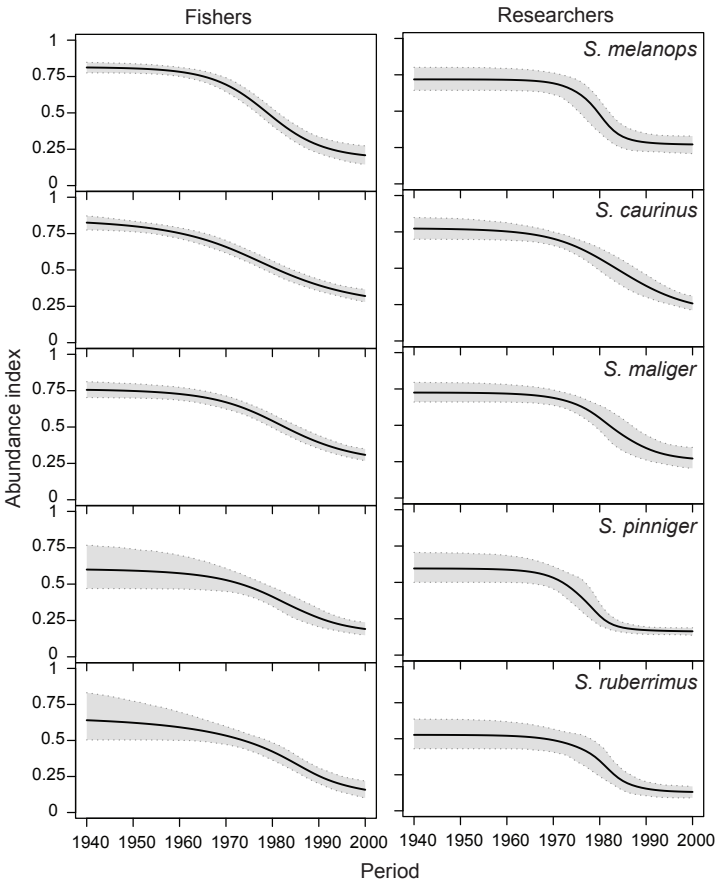
Here, I've summarized differences in the ways researchers and fishers viewed the initial and final abundances for five rockfish species:





Points that fall below the line show species for which fishers reported a higher abundance compared to researchers. Conversely, points that fall above the line show species for which researchers reported a higher abundance compared to fishers. Fishers observed similar or higher abundances than researchers for most rockfish species during the 1940s and 2000s. The exception was black rockfish, which researchers viewed as being higher in abundance during the 2000s compared to fishers.

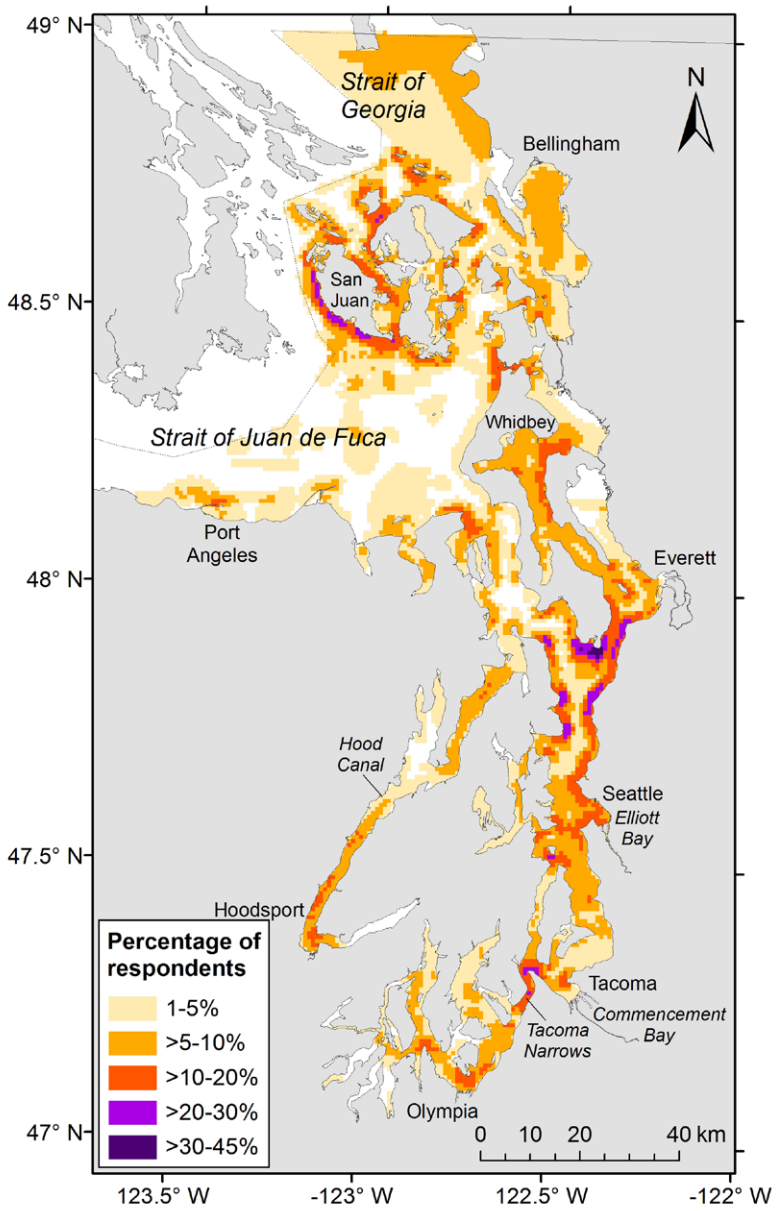
Although fishers tended to report higher abundances compared to researchers, both fishers and researchers reported declines in all five rockfish species. Overall, there was good agreement between fishers and researchers that rockfish declined in abundance, with the most marked changes happening in the 1970s and 1980s. Fishers generally reported more gradual declines over time, whereas researchers perceived more rapid declines that they often described as "crashes" in abundance.



The magnitude of decline since the 1940s was viewed to be similar by researchers and fishers for canary, quillback, and copper rockfish; however, fishermen reported greater declines for yelloweye and black rockfish compared to researchers. It is not clear why differences in perceptions of abundance changes between respondent groups would be substantially greater for these two rockfishes compared to the other three species. However, black rockfish and yelloweye rockfish are distinct from other species due to their coloration, habitat preferences, and value as food. Black rockfish, aptly named, are darker in color and shallower dwelling than other common Puget Sound rockfish species, while yelloweye are brilliant orange and typically caught much deeper than other rockfishes[2]. Both species were commonly described by fishers as "tasty," "desirable," and "good eating." More important or desirable species may be more recognizable by resource users[10]. In fact, black and yelloweye rockfishes are among the most accurately identified rockfish species among boat-based anglers in Puget Sound[11]. A greater degree of specific knowledge about black rockfish and yelloweye rockfish by interviewees may translate into greater variation in perceptions of abundance among respondent groups.

Summary and conclusions

Overall, these results supported our expectation that we would observe differences in perceptions of rockfish trends between respondent groups that differed in aspects of their information environments. Our information environments can be shaped by other factors, in addition to the types of activities we participate in and the timeframe of our observations. For example, perceptions of species abundance may be influenced by harvest regulations, gear selectivity, and access to particular depths or habitats. As a result, an individual's observations may be restricted to certain areas or times of year, or limited to particular species or sizes of fish. Reductions in rockfish bag limits and other management changes since the 1980s[4] may have limited recreational anglers' opportunities to observe rockfish or influenced their views of rockfish abundance. Local knowledge about fish abundance is also place-based, meaning that an individual's knowledge is tied to the specific places where he or she harvested, researched, or observed fish. Therefore, variation in where people fished for rockfish and other species may have led to variation in their views of abundance changes.



Places where people fish for salmon, rockfish, flatfish, and crab in Puget Sound. This map was created by combining fishing maps drawn by respondents. Darker colors show areas of highest use.

Photo courtesy of Ray Buckley

Photo courtesy of Michael Rigik

Concluding Thoughts

The Value of Local Knowledge

This study adds to a growing body of research that shows the value of local knowledge for understanding ecological and environmental change. We found strong agreement between people's observations of marine species abundance and the available scientific data. Respondents showed good overall agreement in their observations of changes over time in Puget Sound fish, invertebrate, and marine mammal populations. This agreement improves our confidence that abundance trends determined from interviews are showing true patterns in nature.

Information obtained from interviews about fish populations is filtered through the experiences, perceptions, and memory of the respondent. As a result, it is important to understand how an individual's information environment can affect their local ecological knowledge. Our results showed the importance of accounting for variation in perception among respondents due to their age or type of experience when interpreting LEK.

A lack of long-term biological monitoring for many ecologically and economically important species is not unique to Puget Sound. In fact, many of the world's most vulnerable and rapidly changing ecosystems are also among the most data-poor. This has led to an increased interest by scientists and natural resource managers in the use of place-based knowledge of resource users to understand long term environmental change[12,13]. **I hope that LEK continues to grow in its use as a source of information that, in combination with scientific data, can help to address challenging environmental problems.**

Rockfish Recovery: Next Steps

One of the most basic but challenging issues facing rockfish recovery efforts is understanding why rockfish populations declined to begin with and what measures can be taken to ensure their recovery. Our study did not seek to answer the question of why rockfish populations changed, only to document those changes. However, many respondents offered ideas about why rockfish had declined since the 1960s. These included impacts of commercial and recreational fishing, increased predation by seals, loss of kelp habitat, pollution, climate change, and management measures that were aimed at increasing participation in rockfish fisheries. During the 20th century, rockfish harvest changed from a predominantly opportunistic subsistence activity to year-round targeting by commercial and recreational fisheries[4]. With improvements in gear technology, increased participation in sport fishing for rockfish, and an expanding human population, commercial and recreational harvest of rockfish peaked in the early 1980s[4]. Conservation actions to limit rockfish harvest were not implemented until declines had already occurred. Even so, a number of respondents in our study commented that they voluntarily stopped targeting rockfish after they noticed evidence of declines or learned that rockfish are long-lived. Another recent study found that 42% of surveyed recreational anglers stopped fishing for rockfish an average of two years before the recreational closure in 2010[11]. As seen in other regions of the west coast, rockfish in Puget Sound may take many years to recover from the legacy of fishing due to their slow growth and late age at maturity. The other factors that interview respondents identified also pose challenges to rockfish recovery.

If fishing is now less of a threat to rockfish in Puget Sound, what steps can be taken to help rockfish recover? This is an important question being addressed by NOAA, the federal agency responsible for developing and implementing a rockfish recovery plan for ESA-listed species in Puget Sound. A draft plan is currently under development and there will be opportunity for public comment prior to release of a final recovery plan in 2015.

NOAA is actively pursuing a number of projects in support of rockfish research and recovery, including:

- NOAA's Northwest Fishery Science Center received funding for a collaborative project with the charter industry to study genetics and demographics of ESA-listed rockfish.

- The Sea Doc Society is partnering with NOAA and local fishing guides to assess rockfish bycatch reduction measures in lingcod and halibut fisheries.
- NOAA is funding Remotely Operated Vehicle surveys conducted by the Washington Department of Fish and Wildlife to learn more about rockfish abundance and habitat use.
- Development of an education/outreach video on listed rockfish species in Puget Sound.
- Analysis of salmon diets in Puget Sound to assess their predation on larval rockfish and other species.
- NOAA is partnering with the Northwest Straits Initiative to host a student who will develop a citizen-based kelp survey.
- NOAA funded the WDFW/Northwest Straits Foundation to continue their derelict fishing net reporting and rapid response program.

If you would like to learn more about any of these ongoing efforts, contact Dan Tonnes, the NOAA rockfish recovery coordinator, at Dan.Tonnes@noaa.gov.

Additional information about ESA-listed rockfish and recovery planning in Puget Sound can be found here:

- http://www.westcoast.fisheries.noaa.gov/protected_species/rockfish/rockfish_in_puget_sound.html
- http://www.westcoast.fisheries.noaa.gov/protected_species/rockfish/rockfish_in_ps_esa_listing.html

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- Beaudreau, A.H., P.S. Levin, K.C. Norman. 2011. Using folk taxonomies to understand stakeholder perceptions for species conservation. Conservation Letters 4:451–463.
- Beaudreau, A.H., P.S. Levin. 2014. Advancing the use of local ecological knowledge for assessing data-poor species in coastal ecosystems. Ecological Applications 24(2):244–256.

Research website

http://sites.google.com/site/annebeaudreau/

Source unknown

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My deepest gratitude goes to the 101 study participants who volunteered their time and knowledge to this research. So much of what I learned from those I had the great fortune to interview will not end up in a published article, but have enriched my understanding of Puget Sound and its people.

Photo courtesy of Jeremy Nash

Photo by A. Beaudreau

"I remember I reeled the rockfish in – it was huge – and my brother said, 'You know that fish is 40 years old,' so I said, 'Well then you'd better take it off the hook and let it go.' I just thought the reality – and that was years and years ago – was this fish has lived for forty years until it got onto my hook. And we just started learning more and more about that, that they were the ones that would breed. We stopped fishing for bottomfish years and years ago… Just seeing how the population is so decimated around [*place name*], which is a pretty remote area, is frightening. When we were up there we didn't have to go to the store. We had the garden and if you could hit bottom you had a fish. Unless it was really running hard and you couldn't hit bottom, it was just a matter of picking out which ones you were going to keep. This was when I was a kid."

- Interview Respondent