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An impediment to consumer choice: Overfished species are sold as Pacific red snapper

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ABSTRACT

Concern over the collapse of many wild-caught fisheries has led to a recent focus on seafood-certification and consumer-driven support of sustainable seafood. However, such conservation strategies depend critically on the accurate labeling of seafood species in marketplaces. Pacific rockfish, a group of >60 species in the genus *Sebastes*, are often marketed as Pacific red snapper, but little is known about the number and identity of rockfish species sold under this name. We used a molecular approach to identify species sold as Pacific red snapper by grocery chains, local fish markets, and sushi restaurants in California and Washington. Using genetic data from two mitochondrial markers (cytochrome-*b* and control region), we identified seven species of rockfish (*Sebastes* spp.), tilapia (*Oreochromis* spp.), and one true red snapper (*Lutjanus campechanus*) in our samples. Among samples identified as rockfish, 56% were identified as species listed as overfished by the National Marine Fisheries Service within the past three years. By effectively permitting all species of rockfish to be sold under a common vernacular name, state and federal agencies compromise the ability of consumers to make informed choices when buying seafood.

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1. Introduction

The world's oceans continue to face extreme fishing pressures despite an increasingly widespread understanding of the state of decline of fisheries worldwide (Pew Oceans Commission, 2003; US Commission on Ocean Policy, 2004). There is growing recognition that incorporating consumer behavior into conservation strategies will be necessary for reversing this trend, and seafood-certification and consumer-education programs are acknowledged as important tools for improving the sustainability of fisheries (Brownstein et al., 2003; Kaiser and Edwards-Jones, 2006). Recent surveys indicate that many consumers are willing to change their purchasing behavior to

help conserve marine resources: In a 2003 survey, 72% of respondents in the United States said they would be more likely to buy seafood that had an “environmentally responsible” label (Seafood Choices Alliance, 2003). In a 2005 survey, 83% of respondents in the United Kingdom felt that overfishing was an important factor that would influence seafood purchases (Seafood Choices Alliance, 2007). In addition, focusing on market forces has proven to be an effective conservation strategy in addressing past fisheries-related conservation problems, including the promotion of dolphin-safe tuna (Kaiser and Edwards-Jones, 2006) and the boycott of swordfish (Brownstein et al., 2003). The increasing recognition of the importance of consumer behavior in marine conserva-

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tion has led to the creation of a number of consumer-education programs around the world (e.g., Australian Marine Conservation Society, Canadian-based Living Oceans Society, Southern African Sustainable Seafood Initiative, UK-based Marine Conservation Society, US-based Seafood Watch and SeaWeb's globally directed Seafood Choices Alliance) and seafood sustainability certification programs (e.g., UK-based Marine Stewardship Council).

A common requirement for the success of all consumer-based choice programs, as well as for fisheries monitoring in general, is accurate naming and labeling of seafood at the point of sale. Without accurate labels, active consumer choices are prevented and fisheries statistics are skewed. In particular, major recognized impediments to seafood-certification programs include mislabeling, misnaming, and the use of vernacular or generic labels for fisheries that contain both sustainable and non-sustainable fished species (Jacquet and Pauly, 2007).

Misnaming or mislabeling of seafood can occur in several forms. Most commonly, a less expensive or low-quality species is named or labeled as a more expensive, higher-quality, or more palatable-sounding species. Examples include Alaskan pollock sold as cod (US Food and Drug Administration [FDA], 2006), spiny dogfish sold as "cape shark" or "rock salmon" (Brownstein et al., 2003), and a variety of snappers (*Lutjanus* spp.) sold as red snapper (Marko et al., 2004). In addition, the Patagonian toothfish (*Dissostichus eleginoides*) is commonly sold as "Chilean sea bass", and many species from diverse fish families (e.g., groupers in the family Serranidae) are commonly sold as cod (family Gadidae). Such substitutions are in many cases illegal if seafood has been transported across state or international boundaries in the United States [Section 403(b) of the federal food, drug and cosmetic act], but within-state regulations on naming vary by locale. Ambiguities can also result when mixed-species fisheries are sold under one vernacular name (e.g. "whitefish" which can include halibut, Alaskan pollock, sole, cod, and black cod). Hold et al. (2001) found that commercial products labeled as salmon could be one of many different species of salmon, including multiple species that are endangered (World Conservation Union, 2006). However, they also found that salmon products labeled with a specific species of salmon (e.g. "chum salmon") were correctly labeled 97% of the time. Even where legal, the practice of misnaming seafood or marketing multiple species under one vernacular name can have important ramifications for market-driven conservation strategies, and such practices can hinder seafood-certification programs and potentially prevent consumers from making informed choices about sustainable purchasing.

Marko et al. (2004) found that 77% of fish products labeled true red snapper (*L. campechanus*) on the East Coast of the United States were products of different species. That study used a genetic market analysis and found intentional mislabeling of a variety lower-quality fishes for substitution as the high-quality and overfished true red snapper. Our study focuses on a fish product named 'Pacific red snapper', which does not exist as a species. In such a case, consumer choice or fisheries documentation depends on a summary view of the species generally included under the Pacific red snapper label.

Under US Food and Drug Administration regulations, 13 species of Pacific rockfish can be sold through interstate commerce under the market name Pacific red snapper in California, Oregon, and Washington (Randolph and Snyder, 1993). Pacific rockfishes (*Sebastes* spp.) are an ecologically diverse genus of fishes that occupy a range of habitats from Mexico to Alaska (Love et al., 2002). Fifty-nine species of rockfish comprise important commercial and recreational fisheries on the West Coast of the United States, and today rockfishes are among the most valuable ground fish in the United States (Love et al., 2002). Several life history characteristics of rockfishes, such as slow growth and late age-at-maturity, result in high vulnerability of many rockfish to overfishing (Parker et al., 2000). Rigorous stock assessments have been carried out for only 15 of the 59 species of rockfishes, and of these, 7 species were estimated to be at 25% or less of their original biomass (Pacific Fishery Management Council [PFMC], 2006a). Because of concerns about stock depletion, numerous restrictions and regulations have been placed on rockfish fisheries in the United States and Canada, including annual harvest quotas, gear restrictions, and area and seasonal closures (PFMC, 2006a).

Using molecular methods, we conducted a survey of various retail outlets in Central and Southern California and Washington to determine the number of species being sold as Pacific red snapper. Specifically, we sought (1) to determine whether species not listed by the FDA are being marketed as Pacific red snapper and (2) to gain a broad understanding of the proportion of fishes being sold as Pacific red snapper that represent overfished species. We consider the results of this survey in light of available knowledge about the status of various rockfish stocks and discuss the impacts of misnaming and mislabeling on market-based conservation strategies.

2. Materials and methods

2.1. Sample collection, DNA extraction and amplification of cytochrome-*b*

We collected 77 whole fish or fillets either labeled as or verbally referred to by vendors as Pacific red snapper from 27 establishments in Central and Southern California and Washington. Samples were purchased in the cities of Monterey, Palo Alto, Menlo Park, Mountain View, Santa Barbara, Bakersfield, California and Seattle, Washington. Samples were purchased at a variety of seafood outlets, including 17 large grocery chains, 3 sushi restaurants, and 7 seafood markets. Sub-samples of each fish or fillet were placed in ethanol for preservation.

Genomic DNA was extracted from each sample using a NucleoSpin DNA extraction kit (BD Biosciences, San Jose, California). A segment of the mitochondrial gene for cytochrome-*b* was amplified by polymerase chain reaction using the following primers: GLUDG-L (TGA CTT GAA RAA CCA YCG TTG) and CB3-H (GGC AAA TAG GAA RTA TCA TTC) (Palumbi and Metz, 1991), and an AmpliTaq PCR Master Mix (Applied Biosystems). We chose to sequence cytochrome-*b* because, at the time of this study, Genbank contained sequences for nearly all the Eastern Pacific rockfishes at this lo-

cus. Recently, however, additional mitochondrial loci (cytochrome-*b*, cytochrome-*c* oxidase subunit 1, 12S rRNA, 16S rRNA, tRNA proline, tRNA threonine and control region) and nuclear loci (recombination activating gene 2 and internal transcribed spacer 1) sequences have been deposited for 97 *Sebastes* species (Hyde and Vetter, 2007). For the species reported here, the topology of species level clades for additional mtDNA regions and for nuclear genes are the same as for cytochrome-*b*. The PCR step-up profile consisted of 95 °C(120 s), 6 × (95 °C(30 s), 45 °C(30 s), 72 °C(40 s)), 34 × (95 °C(30 s), 50 °C(30 s), 72 °C(40 s)). PCR products were sequenced on an ABI 3100 sequencer (Applied Biosystems, Inc., Foster City, California). Cytochrome-*b* sequences have been deposited in GenBank under Accession Nos. EU275902–EU275978.

2.2. Data analysis

Sequences were aligned and edited using the program Sequencher version 4.5 (Gene Codes Corporation, Ann Arbor, Michigan). We included these sequences in an alignment with 55 known *Sebastes* sequences (Rocha-Olivares et al., 1999) from the NCBI database (Genbank accession numbers AF030710–AF030768), and sequences from the genera *Lutjanus* and *Oreochromis*. We used PAUP* (Swofford, 1998) to perform 1000 bootstrap replicates in a neighbor-joining analysis. In addition, we performed a heuristic parsimony analysis with 100 bootstrap replicates, using *Sebastes goodei* as an outgroup.

2.3. Amplification and sequencing of the control region

Because the segment of cytochrome-*b* sequenced was not diagnostic to the species level for two species clusters (*S. melanops*/*S. flavidus* and *S. mystinus*/*S. entomelas*), we sequenced a segment of the control region for the 27 samples that fell into these clusters. Genomic DNA was amplified from these samples and sequenced as above, using *Sebastes*-specific primers for the control region: CR-E: 5'-CCT GAA GTA GGA ACC AGA TG and CR-K: 5'-AGC TCA GCG CCA GAG CGC CG TCT TGT AAA (Lee et al. 1995). We used the primer CR-K in the sequencing reaction. Control region sequences have been deposited in GenBank under Accession Nos. EU272869–EU272892.

We aligned our sequences with a set of known rockfish control region sequences (Cope, 2004, Genbank accession numbers AY345611–AY45855; A. Sivasundar, personal communication) and performed phylogenetic analyses as above. In each case, we used *S. paucipinnis* as an outgroup.

3. Results

3.1. Samples and DNA quality

A 758 bp region of cytochrome-*b* gene was amplified and sequenced for all 77 samples. Twenty-seven samples could not be reliably identified using this locus owing to high sequence similarity between two or more species of rockfishes. The modern rockfish species cluster is thought to have derived from an ancient explosive speciation event (Johns and Avise,

1998) and thus we chose to sequence a different locus that might provide higher resolution between recently diverged species. We amplified and sequenced the mitochondrial control region to obtain resolution within clusters containing more than one species of rockfish (see Fig. 1a). A 502 bp region of the control region was amplified and sequenced for 24 samples. However, three samples could not be amplified at the control region (TSB4, CAL11, MMA8), and are identified as one of two species using cytochrome-*b*.

3.2. Identification of sequences within the rockfish species cluster

We identified 69 of 77 samples as belonging within the *Sebastes* spp., complex (Fig. 1a). Nearly half the samples were identified as Pacific ocean perch (*S. alutus*) (30/69). Seventeen samples were identified as either yellowtail (*S. flavidus*) or black rockfish (*S. melanops*). Ten samples were identified as widow (*S. entomelas*) or blue rockfish (*S. mystinus*). We also identified other species of rockfish at lower frequencies, including four splitnose (*S. diploproa*), four canary (*S. pinniger*), three blackgill (*S. melanostomus*) and one aurora rockfish (*S. aurora*). To provide further confidence in our sample identifications, we calculated the level of genetic variation within and between the identified species (see Tables 1 and 2). In all cases, average pairwise differences within species are lower than between species.

We used the cytochrome-*b* marker to identify samples as Pacific ocean perch, splitnose, canary, blackgill, and aurora rockfish. However, we were unable to distinguish between pairs of species in the case of two of the clades using cytochrome-*b* (see Fig. 1a). The first of these clades contains 17 samples that group with black and yellowtail rockfish. The second contains 10 samples that cluster with widow and blue rockfish. We successfully sequenced 16 of 17 samples, and all were identified as yellowtail rockfish (Fig. 1b). Comparison of control region sequences to reference sequences from California and Oregon (from Sivasundar and Palumbi, unpublished data) showed that 4 of the yellowtail samples in our survey derived from fish caught from the northern stock (Oregon and northwards) while 11 were from the southern stock (California). One sample in the yellowtail/black clade could not be amplified at control region and is identified as belonging to this clade and not as a specific species (MMA8). Two distinct clades are shown for widow rockfish, and one of these falls within a larger cluster containing all the blue rockfish (Fig. 1c). All samples cluster within one of these two widow clades. Three samples (TSB1, TSB2, and TSB3) fall within one clade, and the remaining five samples cluster in the other widow clade (SMB1, CAL2, CAL10, CAL12, and CAL13). Two samples in the widow/blue clade could not be amplified at control region and are not as a specific species (CAL11 and TSB4).

3.3. Identification of sequences outside of the rockfish species cluster

Several of the samples sequenced with cytochrome-*b* (8/77) did not fall within the rockfish clade shown in Fig. 1a. We used the BLAST program (NCBI) to identify the cytochrome-*b* sequences in GenBank with the highest sequence similarity.

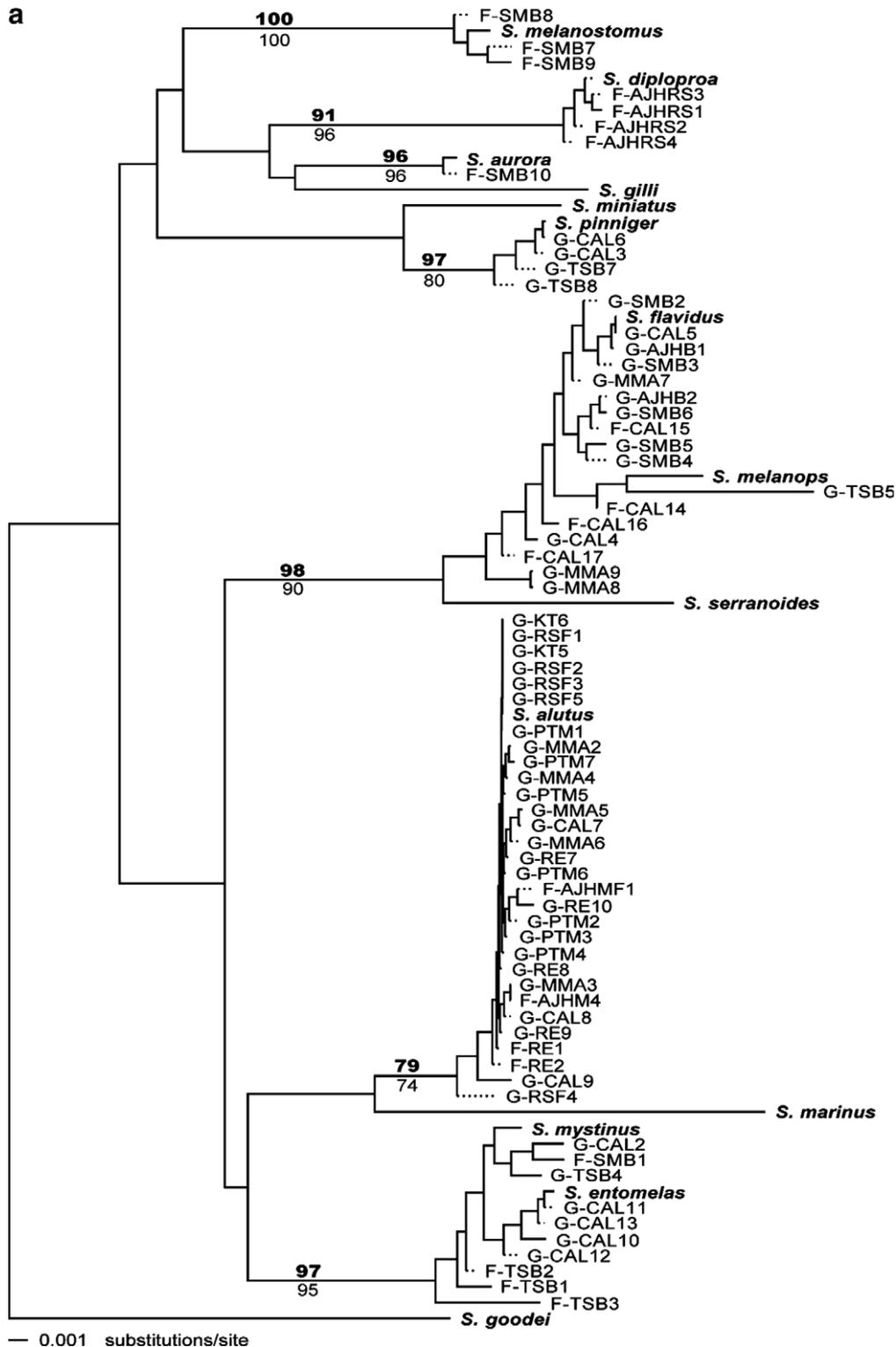


Fig. 1 – Neighbor-joining distance trees (consensus of 1000 replicates) of mitochondrial DNA sequences used to identify Pacific red snapper samples. Location of sample purchase is denoted by G (Grocery Chain) or F (Fish Market). Numbers above branches (bold) are bootstrap values from an unweighted parsimony search with 100 replicates. Numbers below branches are bootstrap values from the 1000 replicates of the neighbor-joining tree. (a) Cytochrome-*b* DNA sequences from samples identified as rockfish (*Sebastes* spp.) and reference sequences. (b) Control region DNA sequences from samples that were identified as either yellowtail (*Sebastes flavidus*) or black rockfish (*S. melanops*) and reference sequences. (c) Control region DNA sequences from samples that were identified as either widow (*Sebastes entomelas*) or blue rockfish (*S. mystinus*) and reference sequences.

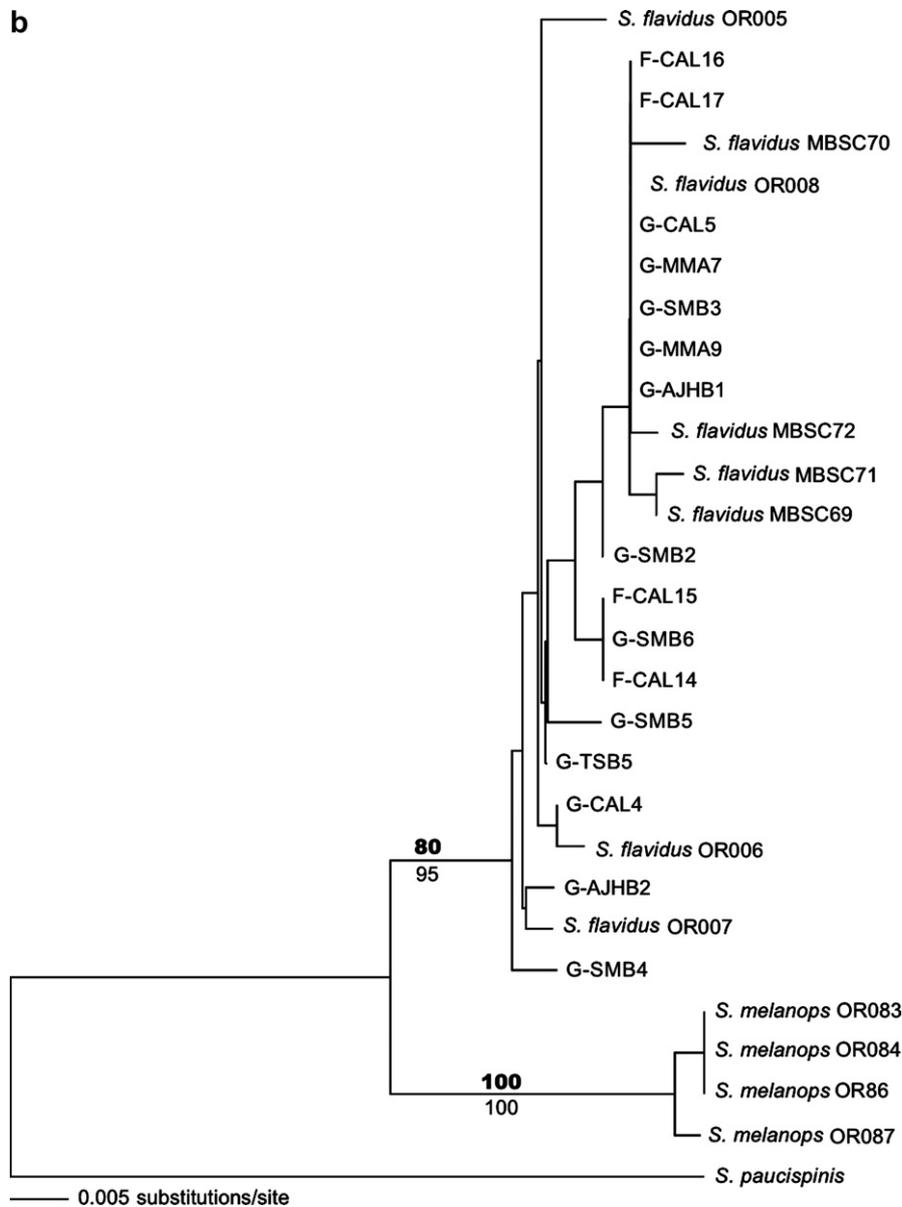


Fig. 1 (continued)

On the basis of these search results, we built two additional trees using the same method as above to determine the sequence identity of these samples. Seven samples are identified as tilapia (*Oreochromis* spp.) and one sample is identified as true red snapper (*L. champechanus*) (data not shown). Although we were unable to distinguish whether samples grouped more closely with *Oreochromis mossambicus* or *O. niloticus* using cytochrome-*b*, both these species of tilapia, as well as hybrids of the two, are commonly farmed in Asia and the Pacific (Romana-Eguia et al., 2004).

4. Discussion

Seventy-seven fish fillets labeled as Pacific red snapper were identified using DNA forensics as coming from 11 different species from 3 taxonomic families of fish. This first mar-

ket-level analysis of the Pacific rockfish, one of the largest groundfish fisheries in North America, exemplifies a common problem faced by seafood-certification programs in efforts to provide information for consumer choice. The use of misleading vernacular names and frequent mislabeling of fishes in the marketplace prevents even the most knowledgeable consumers from making informed decisions. The problem is particularly acute when a group of fishes is marketed under one name because species with different conservation needs are mixed together. This is common in the seafood industry where generic labels such as sea bass, cod or snapper prevail.

Despite the vernacular term Pacific red snapper that is used broadly for marketplace labeling of all Pacific rockfishes, most fishermen report species names at landings (PFMC, 2006b). In 2005, landings data were reported for 39 rockfish species and 10 grouped species (i.e. shelf rockfishes) in Cali-

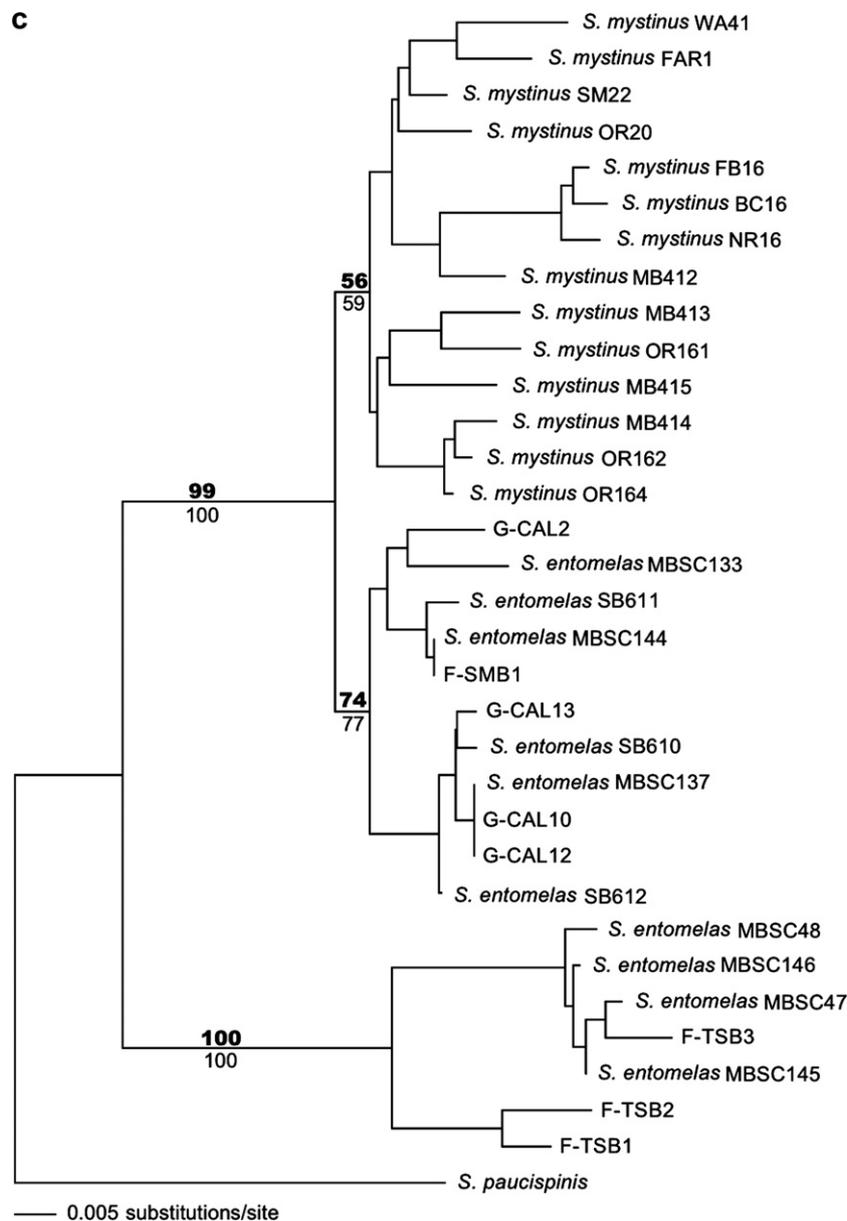


Fig. 1 (continued)

Table 1 – Average pairwise sequence divergence within (bold) and between species at cytochrome-b

	<i>L. campechanus</i>	<i>Oreochromis</i> spp.	<i>S. alutus</i>	<i>S. aurora</i>	<i>S. diploproa</i>	<i>S. entomelas</i>	<i>S. flavidus</i>	<i>S. melanostomas</i>	<i>S. pinniger</i>
<i>L. campechanus</i>	0								
<i>Oreochromis</i> spp.	0.196	0.03							
<i>S. alutus</i>	0.202	0.213	0.001						
<i>S. aurora</i>	0.194	0.215	0.033	0					
<i>S. diploproa</i>	0.210	0.217	0.045	0.024	0				
<i>S. entomelas</i>	0.200	0.219	0.027	0.036	0.042	0.006			
<i>S. flavidus</i>	0.047	0.226	0.032	0.034	0.036	0.032	0.006		
<i>S. melanostomas</i>	0.204	0.221	0.038	0.026	0.033	0.041	0.038	0	
<i>S. pinniger</i>	0.197	0.22	0.04	0.038	0.039	0.042	0.038	0.03	0

fornia. Approximately 80% of sales are of fishes identified at species level (PFMC, 2006b). However, there appears to be a loss of clear identification of fishes between the time of catch

and at the point of sale. Because species of rockfish have vastly different conservation statuses and life histories, grouping rockfishes into one market category drastically de-

Table 2 – Average pairwise sequence divergence within (bold) and between species at control region

	<i>S. entomelas</i>	<i>S. flavidus</i>
<i>S. entomelas</i>	0.062	
<i>S. flavidus</i>	0.069	0.007

creates the power of consumers to purchase sustainable fished products.

4.1. Institutionalized mislabeling in the marketplace

The US Food and Drug Administration (FDA) Seafood List defines “Acceptable Market Names” for imported and domestically available seafood as well as scientific names, common names, and known vernacular or regional names. The FDA and the National Marine Fisheries Service advise the use of either the “Acceptable Market Name” (e.g. ‘rockfish’) or the common name (e.g. ‘yellowtail rockfish’) in labeling seafood products to assure that identity labeling of the seafood complies with federal regulations. The FDA does not encourage use of vernacular names and recognizes that such practices may cause the seafood to be misbranded. Despite this, the Seafood List designates 13 species of rockfish under the vernacular name Pacific red snapper, and use of this vernacular name is widespread on the west coast of the United States.

We found that between 60% and 63% of our samples originated from rockfishes and other fish species that are not listed on the FDA Seafood List. These included five *Sebastes* species (Pacific ocean perch, splitnose, blackgill, blue, and aurora) and two species outside of the *Sebastes* genus altogether (tilapia and true red snapper). The primary purpose of the FDA Seafood list is to prevent fraud across state borders due to mislabeling. Though it would not be illegal for these species to be caught and sold within the state of California, it is unlikely that the samples purchased in California originated from state waters. Pacific ocean perch (*S. alutus*) fisheries operate most heavily in the North Pacific (Alaska and Canada) and catch data indicate only 56 pounds of Pacific ocean perch were caught in California during 2005 as opposed to 11 thousand tons in Alaska (PFMC, 2006b; Department of Fisheries and Oceans [DFO], 2006). Similarly, control region sequences showed that four yellowtail rockfish filets that we purchased were individuals derived from northern populations of this species and 11 from populations of southern clades common south of Cape Mendocino. This means that sales of this species are from fairly widespread fisheries.

4.2. Fisheries status

Of the 13 species that we found marketed as Pacific red snapper in the California marketplace, 56–58% of individuals come from species declared to be overfished by the National Marine Fisheries Service (Fig. 2). The Magnuson-Stevens Fishery Conservation and Management Act of 1976 mandates that the National Marine Fisheries Service prevent overfishing, and achieve, on a continuing basis, the optimum yields from federally managed fish stocks. Pacific rockfish stocks are designated as overfished if spawning stock abundance declines to

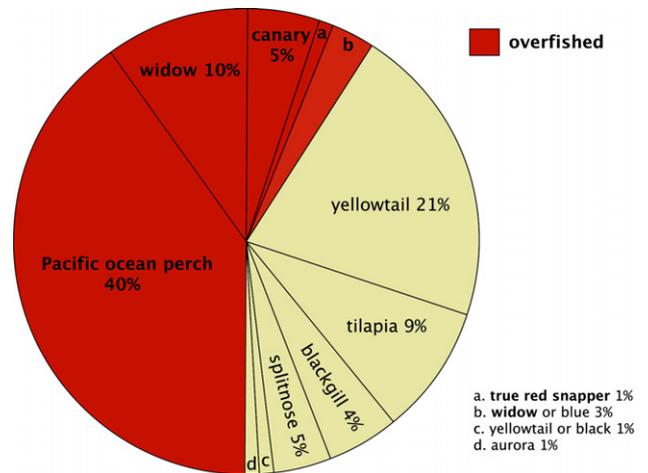


Fig. 2 – Percent of Pacific red snapper samples (n = 77) that have been declared overfished within the past three years by the National Marine Fisheries Service.

25% of its estimated “virgin biomass” (the spawning population size if the stock had never been fished) (PFMC, 2006a).

The Pacific ocean perch (*S. alutus*), unrelated to the true perches, comprises the largest portion of our samples (30/77). This species ranges from California to the Kuril Islands (Hanselman et al., 2003), and are long-lived and slow-growing, with maximum age estimated to be in excess of 90 years (Love et al., 2002). The resilience of this species to overfishing is very low with a minimum population doubling time of more than 14 years (Musick et al., 2000). Currently, the species has an overfished status in California, Oregon and Washington and is undergoing an extensive rebuilding plan set forth by the Pacific Fisheries Management Council in 1981 (Hamel, 2005). Much larger stocks exist in both Canadian and Alaskan waters, and are not considered overfished there (Hanselman et al., 2006; DFO, 2006; PFMC, 2006a).

In addition to the Pacific ocean perch, we also found three other species among our samples that have been listed as overfished by the National Marine Fishery Service within the past three years: canary rockfish, widow rockfish and the true Atlantic red snapper. Among our samples, we identified 10–13% as widow rockfish (*S. entomelas*) and another 5% as canary rockfish (He et al., 2005; Methot and Stewart, 2005). We also identified one sample belonging to the overfished species ‘true red snapper’ (*L. campechanus*) (National Marine Fisheries Service, 2006). The status of this stock is influenced not only by mortality rates in the directed fishery but also by high by-catch mortality rates from shrimp trawl fisheries, a trend also seen for overfished rockfish species due to bycatch in halibut fisheries (O’Connell and Carlile, 2006).

About half of our samples originated from six species of rockfish that are not declared overfished at present. These include the splitnose (*S. diploproa*), blackgill (*S. melanostomas*), blue (*S. mystinus*), black (*S. melanops*), aurora (*S. aurora*) and yellowtail (*S. flavidus*) rockfish. Several of the fish are important recreational targets in California, but most have been recorded to have low commercial landings. For example in 2006, the year we collected our samples, splitnose, blackgill, blue,

black, aurora and yellowtail rockfish were listed with commercial landings of 8, 66, 20, 160, 0.4 and 433 metric tons, respectively, making up collectively about 1% of the species-specific landings recorded in that year. By contrast, ocean perch provided 23,000 tons of landings in 2006 making up about half the named catch. That 32% of our sample derives from species that appear in 2006 fisheries statistics to account for only 1% of the catch may mean that landings of these species are disproportionately represented in the 26,000 tons of unnamed rockfish catch reported that year, or that the pool of fish products sold as Pacific red snapper is a highly non-random selection of *Sebastes* landings.

4.3. Sushi

We found that none of the Pacific red snapper samples from sushi restaurants were rockfish. Although our survey was not intended as a comprehensive study between types of markets or restaurants, seven of eight samples purchased as sushi were unexpectedly found to be tilapia (*Oreochromis* spp.). One sample was identified as true red snapper (*L. campechanus*). These items were all labeled as 'Tai' on the menu, a Japanese fish that American sushi restaurants often substitute with red snapper, sea bream and other similar tasting fishes. This substitution of a cheaper substitute (tilapia) constitutes economic fraud under FDA regulations.

5. Broader implications

The data presented here underscore that a single vernacular or generic market label can group together for sale fish that have markedly different conservation statuses. Our study focuses on the molecular identification of fishes sold as Pacific red snapper, but this issue is pervasive in seafood markets. Even when legal, this practice effectively eliminates the possibility that seafood-certification programs (such as the Marine Stewardship Council) could certify any part of the Pacific rockfish fishery as sustainable because this fishery contains overfished as well as sustainable species. By contrast, some species of rockfish would likely meet the requirements for Marine Stewardship Council certification if they were marketed under individual species names. Seafood-certification and consumer-education programs are expanding to mainstream markets. In the United States, WalMart recently announced that it will purchase all of its wild-caught seafood from Marine Stewardship Council-certified fisheries within five years (Jacquet and Pauly, 2007). In Europe, a 2005 Greenpeace campaign that began in the UK, and was more recently introduced in France and Austria, challenged supermarkets to sell only sustainable seafood. In the UK, this campaign has led to supermarket wars where retailers compete for a top place in the Greenpeace league tables and many supermarkets have now removed endangered or threatened species from their shelves (Seafood Choices Alliance, 2007).

The growing market for sustainable seafood is analogous to the organic movement that led to the establishment of the legal organic food label by the US Department of Agriculture in 2002. We propose that the US federal government follow suit and develop legal standards for a sustainable fishery

label. At the minimum, we suggest that multi-species fisheries, such as Pacific red snapper, are labeled by species so consumers can discriminate between sustainable and overfished categories in the marketplace.

Though seafood-certification and consumer-education programs show great promise as tools for conserving ocean resources, the effectiveness of such programs in the future will depend on accurate conservation information reaching the consumer in the marketplace.

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