Rockfish in Puget Sound: An ecological history of exploitation

Article *in* Marine Policy · September 2010

DOI: 10.1016/j.marpol.2010.02.008

CITATIONS
27

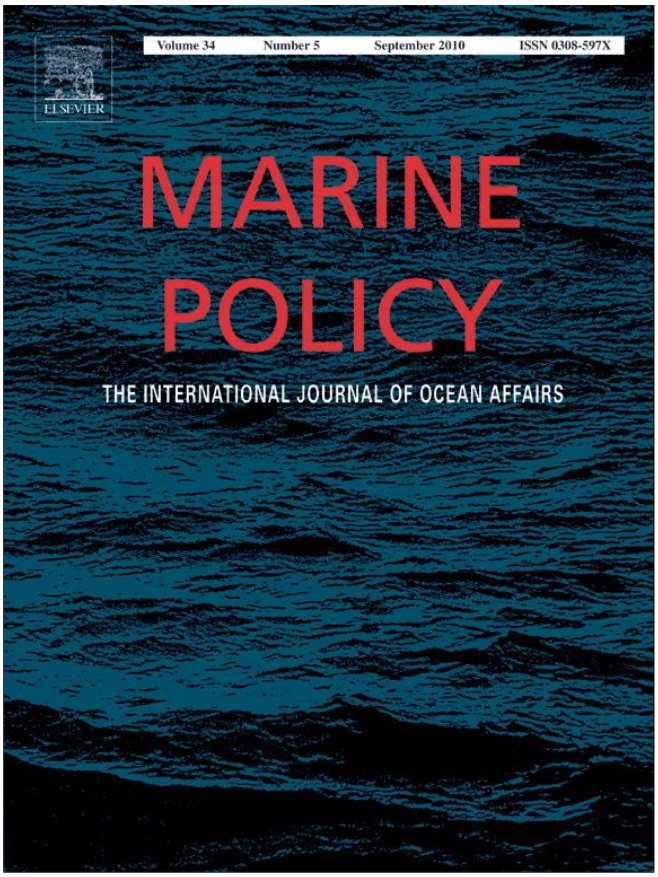
READS
104

3 authors:

Gregory Williams
Northwest Fisheries Science Center
84 PUBLICATIONS **1,276** CITATIONS
SEE PROFILE

Phillip Levin
Northwest Fisheries Science Center
200 PUBLICATIONS **6,052** CITATIONS
SEE PROFILE

Wayne A. Palsson
National Oceanic and Atmospheric Administration
23 PUBLICATIONS **154** CITATIONS
SEE PROFILE



Marine Policy 34 (2010) 1010–1020

Contents lists available at ScienceDirect

Marine Policy

journal homepage: www.elsevier.com/locate/marpol

Rockfish in Puget Sound: An ecological history of exploitation

Gregory D. Williams [a,*], Phillip S. Levin [b], Wayne A. Palsson [c]

[a] Pacific States Marine Fisheries Commission, 2725 Montlake Boulevard East, Seattle, WA 98112, USA
[b] NOAA Fisheries, Northwest Fisheries Science Center, 2725 Montlake Boulevard East, Seattle, WA 98112, USA
[c] Washington Department of Fish and Wildlife, Marine Resources Unit, 16018 Mill Creek Blvd., Mill Creek, WA 98012-1296, USA

ARTICLE INFO

Article history:
Received 20 January 2010
Received in revised form
10 February 2010
Accepted 12 February 2010

Keywords:
Rockfish
Sebastes
Puget Sound
Historical fisheries
Exploitation
Ecosystem management

ABSTRACT

In Puget Sound, WA (USA), rockfish (*Sebastes* spp.) have significantly declined in abundance, with multiple petitions to list individual species under the Endangered Species Act. In order to better understand the ecological legacy of rockfish fishing to the Puget Sound ecosystem, the local history of rockfish exploitation was reviewed, focusing on the socioeconomic forces and management decisions which influenced the trajectory of landings. Rockfish have always been harvested for human consumption in the region, but over time exploitation patterns have changed from an opportunistic subsistence activity by indigenous peoples, to a year-round target of commercial and recreational interests. Annual commercial and recreational harvests together peaked (almost 400 mt) in the early 1980s as anglers' attitudes changed, gear technology improved, rockfish became more familiar to the market, human population increased, and agency programs promoted fisheries to sustain employment. Rockfishes were generally not managed intensely or with conservation goals in mind until the late 1980s, in part due to scientific shortcomings and a lack of resources. By the time management actions were deemed necessary, the greatest harvest had already occurred. However, the low intrinsic productivity of most rockfish species suggests that the legacy of fishing will remain for years to come. As managers strive to restore the integrity and resilience of Puget Sound, they must realize the significance of historical fishery removals to the ecosystem and use the proper social and economic incentives to drive individual behavior toward these ecosystem goals.

Published by Elsevier Ltd.

1. Introduction and approach

In recent years both fisheries scientists and marine conservation biologists have looked to the past to uncover how historical impacts shaped current ecosystems and to use historical conditions as reference points for the recovery of degraded ecosystems [1–4]. In the case of fisheries, there is clear recognition that the history of exploitation has influenced the structure and function of present-day marine ecosystems, and understanding the ecological legacy of fisheries can increase the effectiveness of management aimed at recovering degraded ecosystems. Importantly, historical perspectives on fisheries management may also highlight constraints to management efforts since the historical legacy of decades of fishing may limit policy and management options.

Understanding the history of management is particularly important in long-lived, low-productivity species [5]. For such species, effects of humans may not be evident for many years, thus introducing a response lag from population impact to management need. For instance, the demise of juvenile and subadult sea turtles lost through harvest or bycatch may have remained unseen and unrealized because human monitoring focused on adult nesting females, who delay maturity for 10–60 years [6]. Similarly, the feedback lag between management action and population response may be protracted in long-lived fish populations with long generation times, delayed maturity, and sporadic recruitment.

Rockfishes (*Sebastes* spp.) are a diverse group of marine fishes (about 102 species worldwide and at least 72 species in the northeastern Pacific) [7], and as a group, are among the most common groups of bottom and mid-water dwelling fish on the Pacific coast of North America [8]. Adult rockfish can be the most abundant fish in various coastal benthic habitats, from shallow coastal habitats, such as kelp forests, to deep submarine canyons. Despite their ubiquity, rockfishes tend to have a number of life history traits that make them susceptible to fishing or other anthropogenic perturbations. In general, rockfish have long life spans, often exceeding 50 years, are slow to mature, and have very low first-year survival, resulting in long generation times [8]. Successful recruitment from a pelagic larval to juvenile stage is highly variable [9–11], thus making recovery of depleted

* Corresponding author. Tel.: +1 206 861 7604; fax: +1 206 860 3475.
E-mail addresses: greg_williams@psmfc.org, greg.williams@noaa.gov (G.D. Williams).

0308-597X/$ - see front matter Published by Elsevier Ltd.
doi:10.1016/j.marpol.2010.02.008

rockfish populations slower than might be expected given their high fecundity. Moreover, adults typically show limited movement [12], and thus rockfish often exist as metapopulations with local subpopulations connected by the dispersal of pelagic juveniles [13].

Along the west coast of the US, a number of rockfishes have undergone substantial declines over the last three decades [14–17], with several species now considered overfished [18]. Likewise, a number of rockfishes have showed significant reductions in abundance over the last 30 years in Puget Sound, which has a unique but considerably less diverse rockfish assemblage (28 spp) than the outer coast (40 spp) [8,19]. These declines led to petitions to list 14 Puget Sound rockfish species under the US Endangered Species Act (ESA) in 1999. The National Marine Fisheries Service (NMFS) declined to review 11 of the 14 species citing a lack of information necessary to conduct a formal status review [20], and after conducting a status review of the remaining three species (copper rockfish *Sebastes caurinus*, quillback rockfish *S. maliger*, and brown rockfish *S. auriculatus*), NMFS concluded that ESA listing was not warranted [21]. However, in 2007 NMFS received another petition to list five of the 11 rockfishes that were previously denied. These were bocaccio *S. paucispinis*, canary rockfish *S. pinniger*, yelloweye rockfish *S. ruberrimus*, greenstriped rockfish *S.elongatus* and redstripe rockfish *S. proriger*. After conducting a status review in 2009 [22], canary rockfish and yelloweye rockfish were proposed to be listed as threatened and bocaccio as endangered [23].

The history of fisheries exploitation of rockfish in Puget Sound is reviewed in this paper, with a focus on those species recently considered by NMFS for ESA listing. The review spans fisheries from pre-Euroamerican colonization to the present and details the timeline of exploitation. It also examines how socioeconomic forces and management decisions, coupled with scientific shortcomings of the time and the inherent ecology of rockfishes, paralleled the trajectory of landings in Puget Sound.

2. Study region

Greater Puget Sound is a fjord-like estuary located in northwest Washington State, and is part of a larger inland marine system (the Georgia-Fuca system or Salish Sea) situated between southern Vancouver Island and the mainland coasts of Washington State and British Columbia [24,25]. The geographic extent of Puget Sound has been variously defined by author and discipline; however, most of the fisheries and management actions described here incorporate all US waters east of the Sekiu River in the Strait of Juan de Fuca, with Admiralty Inlet used as a convenient demarcation between "northern" and "southern" Puget Sound (Fig. 1). Interconnected basins separated by shallow sills define the geometry of the system and play a pivotal role in basin dynamics through lateral water exchange. Depths range to almost 300 m in steep walled channels, which are fringed by a relatively narrow band of shallow nearshore habitat, except where major rivers form more extensive tidal deltas [26]. The amount of shallow (<38 m) rocky habitat is orders of magnitude larger in the northern (210 km^2) portion of Puget Sound as compared to southern portion (11 km^2) [27]. Circulation is driven by tidal currents, freshwater outflow from rivers, dense seawater inflow from marine waters, and wind strength and direction [28,29]. Typically, a two-layered pattern of estuarine circulation is superimposed on the tides, causing stratification in the summer as a result of river discharge and solar heating, and mixing in the winter as a result of cooling and wind. Subsurface temperatures in southern Puget Sound average between 8 and 12 °C, whereas salinities in the deeper portions generally remain between 29 and 30 practical salinity units; dissolved oxygen varies seasonally, with lowest levels of about 5.5 mg/L occurring at depth in summer months [26].

3. Historical patterns of rockfish exploitation

3.1. Pre-Euroamerican subsistence fisheries: <1900

Evidence of rockfish use by native Americans in the Pacific Northwest is contained in first-hand oral histories, observations of ethnographers, and the archaeological record. These sources together suggest that before and during Euroamerican contact rockfish were primarily used as an opportunistic subsistence resource by native people who harvested them for immediate consumption [30]. Rockfish and other large demersal fishes were caught by hook and line or basket traps from dugout canoes and were probably consumed by individuals or small family groups [31,32]. In contrast, other important marine fishes such as salmon *Oncorhynchus* spp. and herring *Clupea pallasi*, which aggregate seasonally in large schools, were harvested collectively for drying, storage, and trade in vastly greater quantities. It should be noted that rockfish (family Scorpaenidae) are rarely differentiated below the family level in archaeological records due to morphological similarity in skeletal elements [31]; similarly, oral histories and ethnographic observations are also usually limited to broad taxonomic-level groupings due to terminological confusion (see Table 1) between native fishers, anthropologists, and fisheries scientists [30] (pers. comm., R. Kopperl, UW Burke Museum).

Fish bones in zooarchaeological records provide some of the best long-term evidence of human resource utilization by native American communities, but have been used only recently to systematically test theories about resource use and culture change [33]. In a review of Pacific Northwest zooarchaeological data compiled over the last 25 years [33], rockfish were found to hold some importance as a resource, being present at 18 of 38 assemblages, but were never ranked first in relative abundance among all fish families at any single site. In contrast, the significance of salmon was supported by its ubiquity and relative abundance in these deposits, being present in all 38 assemblages and ranked first in over half of them.

There is some evidence of regional distinctions in the relative dependence on rockfish by Northwest native cultures as one moves from the rocky outer coast into the more protected waters of Puget Sound. Prehistoric zooarchaeological sites on the outer coast are well-known for bottomfish, and in some cases, rockfish. For example, rockfish were the most abundant fish taxon recovered from shell middens in a prehistoric coastal village on the west coast of Vancouver Island, with rockfish bones representing 66% of over 23,000 identified fish skeletal remains [31]. Rockfish were a focal component of the village fishery for over 1500 years, with varying impacts on abundance and total length, perhaps due to ethnographic harvesting practices. Other coastal sites in Washington State suggest a similar dependence on bottomfish, with rockfish bones representing a significant proportion of identified fish remains: 9–11% and 15% at the Hoko River and Ozette assemblages, respectively [33].

In comparison, rockfish harvest in the San Juan Islands reflect a more opportunistic subsistence resource pattern, based on the relative paucity of rockfish bones identified from archaeological sites. For instance, over 7,000 fish remains were analyzed from a midden in Watmough Bay, Lopez Island, with 2,450 of those bones identified at least to the taxonomic level of Order [34]. Only four rockfish bones were identified from the midden, which consisted mainly of salmon remains; these results were not

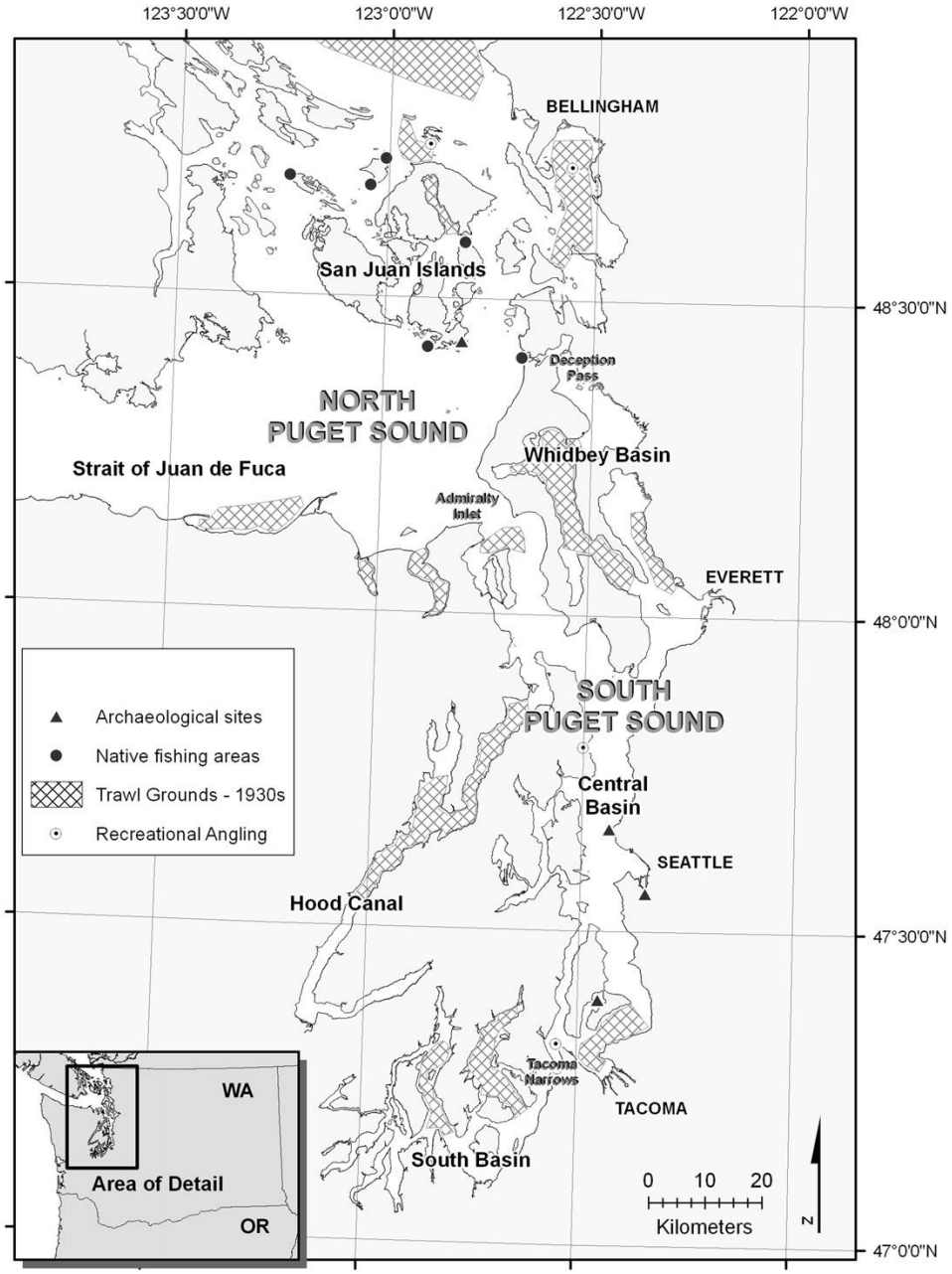


Fig. 1. Map of Puget Sound geographic features and place names. Symbols indicate the following: major zooarchaeological sites (filled triangle), traditional native American rockfish harvest areas (filled circle), major groundfish trawling grounds during the 1930s (crosshatched polygon), and multiple records of yelloweye, canary, and bocaccio rockfish from recreational catch during 1960–1970s (open circle with dot).

particularly surprising, considering Watmough Bay was an historically documented reef-net salmon fishing area [30]. However, it is notable that nearly 10% of the bones from the excavation were from greenlings (family Hexagrammidae), bottom-dwelling fishes that co-occur with many rockfishes, suggesting bottom-fishing occurred and rockfish were either not captured or not retained. Other San Juan Island excavation sites, such as English camp in Garrison Bay, show a similar trend of substantially more greenling than rockfish remains (20:1 ratio) in shell middens [35]. Places "known" for rockfish in San Juan Island ethnological records and oral histories include Deception Island (Deception Pass), Turn Point on Stuart Island, Iceberg Point on Lopez Island, Peavine Pass on north Blakely Island, and Point Disney and Point Hammond on Waldron Island [30] (pers. comm., R. Barsh, Kwiaht: Center for Historical Ecology of the Salish Sea; http://www.kwiaht.org/index.html) (Fig. 1).

Archaeological records suggest rockfish were also harvested opportunistically within southern and central Puget Sound. The Burton Acres shell midden on Vashon Island in southern Puget Sound showed herring use to be the predominant focus of this site, and rockfish bones, though present, represented less than 0.5% of the identified fish remains [36]. A similar pattern was

Table 1
Alternative historical names of the more common rockfish species in Puget Sound; "key management species" according to Pedersen and DiDonato [46] are noted in bold.

Scientific name	Common name	Alternative names	Max length (cm)	Life span (year)	50% Matur. (year)	Fecund. [eggs] (1000s)	Habitat	Common depth range (m)
Sebastes auriculatus	**Brown rockfish**		56	34	4–5	55–339	B	120
Sebastes caurinus	**Copper rockfish**	Common rock cod[a]; Northwestern rockfish[b]	66	50	6–7	16–640	B, NB	90
Sebastes elongatus	Greenstriped rockfish	Olive banded rock cod[a]	43	54	7–10	11–295	B	100–250
Sebastes emphaeus	Puget Sound rockfish		18	22	1–2	3–58	NB, P	3–366
Sebastes flavidus	**Yellowtail rockfish**		66	64		57–1993	P	90–180
Sebastes maliger	**Quillback rockfish**	Yellow backed rock cod[a]/rockfish[b]	61	95	11		B	0–274
Sebastes melanops	**Black rockfish**	Black bass[c]	69	50	6–7	125–1200	P	<55
Sebastes miniatus	Vermilion rockfish	Vermilion rock cod[a]; Rasher[a]	76	60	5	63–2600	B	50–150
Sebastes paucispinis	**Bocaccio**	Rock salmon[a]	91	50*		20–2300	B, NB	50–250
Sebastes pinniger	**Canary rockfish**	Orange rockfish[a,b,d]; Red Rock Cod[c]	76	84	7–9	260–1900	NB	80–200
Sebastes proriger	Redstripe rockfish		51	55			B	150–275
Sebastes ruberrimus	**Yelloweye rockfish**	Red rock fish[b,c]; Red snapper[a,b]; Tambor[c], Rasphead rockfish[e]	91	118	7*	1200–2700	B	91–180

Maximum size, life span, 50% maturity, fecundity, predominant adult habitat association (B=Benthic/On bottom; NB=Near Bottom; P=Pelagic /Water column), and depth range from Love et al. [8]; blank cells indicate lack of published data.
*Estimated.

[a] Smith [43].
[b] Kincaid [39].
[c] Jordan and Starks [38].
[d] Heyamoto et al. [40].
[e] Buckley [50].

observed at one of the most intensively studied archaeological middens in Puget Sound—the West Point midden in Seattle, Washington. Rockfish remains (six bones total) were limited to the two earliest defined periods of occupation [33], with changes in the fish bone assemblage generally attributed to changes in the function of the site, from a generalized fishing/hunting/gathering campsite to a more specialized clam gathering and salmon fishing camp (pers. comm., R. Kopperl). Similarly, at an archaeological site on the Duwamish River near downtown Seattle, rockfish bones were present in very small quantities compared to salmon, flatfish (family Pleuronectidae), sculpin (family Cottidae), and others [33]. Thus, the limited available information suggests that although rockfish were fished by indigenous peoples in Puget Sound, their use does not appear to be associated with large-scale systematic exploitation.

3.2. The rise and decline of commercial fisheries: 1900–1980s

The earliest accounts of Puget Sound's fisheries after European contact provide anecdotal accounts of species' relative abundance and reported locations of occurrence. Overviews of British Columbia and Washington saltwater fisheries by the US Fisheries Commission at the turn of the century focused on "useful" fishes such as salmon, halibut *Hippoglusus stenolepis*, and sturgeon *Acipenser* spp., which figured prominently in the catch at the time [37]. Rockfishes are not mentioned explicitly in these reports and are assumed to represent what the authors presciently termed, "a reserve stock [of saltwater species] which will be drawn upon more and more with the increase of local population".

Scientific accounts of the time, however, do note the relative abundance and market importance of various rockfish species in Puget Sound. For example, "black bass" *S. melanops* were considered "abundant and a food fish of value", "red rock fish" or "tambor" *S. ruberrimus* were "taken with hook and line in some abundance in Puget Sound"; *S. caurinus* were "very common; brought into the market in abundance", and "red rock cod" *S. pinniger* were "abundant in rather deep water" (see Table 1 for alternate common names) [38]. Other texts acknowledged the family Scorpaenidae constituted "one of the most important and valuable groups of fishes found on the Pacific Coast" [39]. An annotated list of Puget Sound fishes documented 13 species of rockfish that were known to inhabit Puget Sound, including the "orange rockfish" *S. pinniger* that was "abundant in deep water", and the "red rockfish or red snapper" *S. ruberrimus*, the largest of this group, "common in deep water" and "brought to market in considerable quantities" [39].

While large-bodied halibut and plentiful runs of salmon were the primary targets of early commercial fisheries, other species familiar to traditional European and Northeast consumers, such as flatfish and cod, were targeted by a small trawl fishery. The bottom trawl fishery operated within Washington's territorial waters since perhaps the 1880s [19], and this fishery evolved and changed over time guided by market demand, technological advances (e.g. radar, fathometers, Loran, and echo sounders), and management actions [40–42]. The fishery was often divided into two distinct geographic groups: an "inside" or "territorial" Puget Sound fishery, which included catches of everything inside of a line extending north of Cape Flattery, and an "outside" or "extraterritorial" ocean fishery which included the Washington coast and waters off Vancouver Island [19,40,43]. The "outside" trawl fishery was only begun in the 1930s, but high catch rates more than compensated for disadvantages associated with time lost to poor weather and longer transit to the Seattle market. As

an example, catch rates of flatfish from the outside fishery (6741 kg landing^{-1}) far exceeded inside rates (383 kg landing^{-1}) in 1935, soon after the outside fishery was developed [43].

The "inside" Puget Sound trawl fishery largely depended upon local demand for fresh fish and was exploited by a small number of trawlers, augmented seasonally by boats temporarily converted from a variety of other fishing strategies (gillnet, purse seine, etc.) [42,43]. Trawl fishing inside Puget Sound was most intense in the winter and early spring, a situation influenced in part by weather conditions on the outer coast, new vessels entering the fishery after the end of the salmon and halibut seasons, and seasonal declines in the productivity of flatfish grounds in "outside" waters. One of the first scientific reports on Puget Sound commercial fisheries focused on this fleet of otter trawlers which targeted flatfish landed for the Seattle market during the 1930s [43]. The fishery occurred primarily over relatively soft-bottom habitats in greater Puget Sound, with 12 important trawl fishing areas noted based on their relative productivity (Fig. 1). Seven rockfish species were reported as being taken in inside waters, including canary, yelloweye, and greenstriped rockfish; however, only copper and quillback rockfish were considered abundant enough to be significant in commercial landings [43].

Initially, rockfish were a minor, non-targeted species, but gradually came to fill a market niche, both seasonally when the salmon and halibut fisheries were slow, and over time as they became more common in the market. From 1955 to 1964 the Puget Sound trawl fishery involved about 50 vessels that primarily harvested Pacific cod *Gadus macrocephalus*, English sole *Parophrys vetulus*, and starry flounder *Platichthys stellatus* (Table 2). In general, the market demand for rockfish was low, but climbed during the winter and spring months due to the scarcity of fresh fish such as salmon and halibut. Fishing for rockfish was similarly limited by market demand, which on the outer coast often led to fishermen avoiding areas where rockfish were found or discarding poundage exceeding the trip limits set by their processor [40]. Within Puget Sound, rockfishes were considered "scattered around", and principally comprised of copper, quillback, and canary rockfish [42]. Annual landings from 1955 to 1964 averaged less than 100 metric tons (mt) $\cdot$ year^{-1}, a level considered rather insignificant (Table 2; Fig. 2a) [42]. In fact, Puget Sound rockfish catches generally increased from 1955 to 1959, but catch rates remained below 10 kg h^{-1} in most years, almost 5 times lower than the next most productive "outside" region, leading biologists to conjecture that this was "all the inside waters are capable of producing" [40].

By the 1970s, Puget Sound groundfish fisheries were being expanded and publicized to reduce social and economic stress from displacement of Washington-based US vessels from Canadian waters and the reduction in salmon-fishing opportunities from the 1974 Boldt decision [19]. Booming fisheries for hake *Merluccius productus* and dogfish *Squalus acanthias* were developed in Puget Sound, and catches of all bottomfish combined rose above 4000 mt $\cdot$ year^{-1} from 1974 to 1985 (Fig. 3a) [44]. The upsurge in harvest of other more abundant (and valuable) bottomfish species may have masked the concomitant decline of rockfish stocks. Commercial rockfish harvest during most years represented about 1% of the total bottomfish harvest by weight, and trends are swamped by the rapid rise, and equally rapid decline, of these other prominent and more valuable fisheries (Fig. 3a).

As commercial fishing practices for bottomfish species changed, so did the relative focus on various habitats associated with these practices. Bottom trawling continued to account for most of the recorded commercial rockfish harvest at the outset of the 1970s (Fig. 3b). However, rockfish harvests increased into the 1980s (Fig. 2a) as other techniques such as modified trawl roller gear, bottomfish trolling, and handline jigs were developed to specifically target rockfish and lingcod in complex rocky reef habitats. In fact, the handline jig fishery, which targeted fresh fish for specialty markets, began to account for much of the rockfish catch for several years during the late 1980s (Fig. 3b). The non-target bycatch of rockfish also expanded from growing set-line and set-net fisheries that targeted Pacific cod and spiny dogfish. These gears appeared to be selective for particular rockfish species in some regions, with approximately 70% (by weight) of the rockfish bycatch in commercial set-nets during 1984 represented by bocaccio in the Central and South Sound regions and 20% by yelloweye rockfish in the San Juan Island region [44]. Set lines were similarly effective for catching bocaccio in Hood Canal (30% of rockfish catch by weight) and South Sound (50%), and for yelloweye in the Strait of Juan de Fuca (50%) and Hood Canal (30%). Subsequent rockfish species composition estimates made between 1988 and 2003 [19] show similar trends by gear type, although the actual number of observations were low and rockfishes were a relatively rare bycatch component.

By 1980, statements about limited rockfish production in "inside waters" [40] appeared unfounded, as commercial landings of rockfish in Puget Sound peaked at over 160 mt, with another peak in 1989 of almost 130 mt (Fig. 2a) [19]. The new availability and popularity of rockfish in the marketplace was reflected in regional cookbooks. A review of cookbook recipes published in Puget Sound over the last 125 years found that rockfish recipes were nearly absent in cookbooks published before 1970 [45]. However, after 1980 more than 80% of cookbooks included rockfish. The increasing popularity of rockfish may have been reinforced by demographic shifts in the Puget Sound region. For instance, increases in commercial targeting of rockfish were attributed to the emergence of a new market associated with people of Asian descent "who recently moved into the Puget Sound region" [46]. Between 1970 and 2000 the central Puget Sound region experienced substantial growth, increasing by over 1.3 million people [26]. Seattle alone reflected an increasingly diverse population, with Asians and Pacific Islanders accounting for almost 12% of the population in 1990, a 56% increase over 1980 [47].

The rockfish yields of the 1980s were short-lived, however, and commercial harvests declined substantially during the 1990s to annual levels that never again exceeded 50 mt, and have not

Table 2
Average annual landings (mt) and average price per kg of fish species or group landed by the Puget Sound trawl fishery from 1944 to 1964 (Holmberg et al. [42]).

Species group	Puget Sound—annual landings (mt)	Years	Average price/kg	Comments
Rockfish	<45	1955–1964	$0.023	
Pacific cod	>1350	1955–1964		
English sole	900	1945–1964		
Starry flounder	150	1944–1964		
Lingcod (trawl)	>35	1955–1964		*100 mt/year by troll
Dover sole	<25	1951–1964	$0.029	Catch decline by 1964
Small sole, walleye pollock, skate, hake			$0.014	Sold as mink food

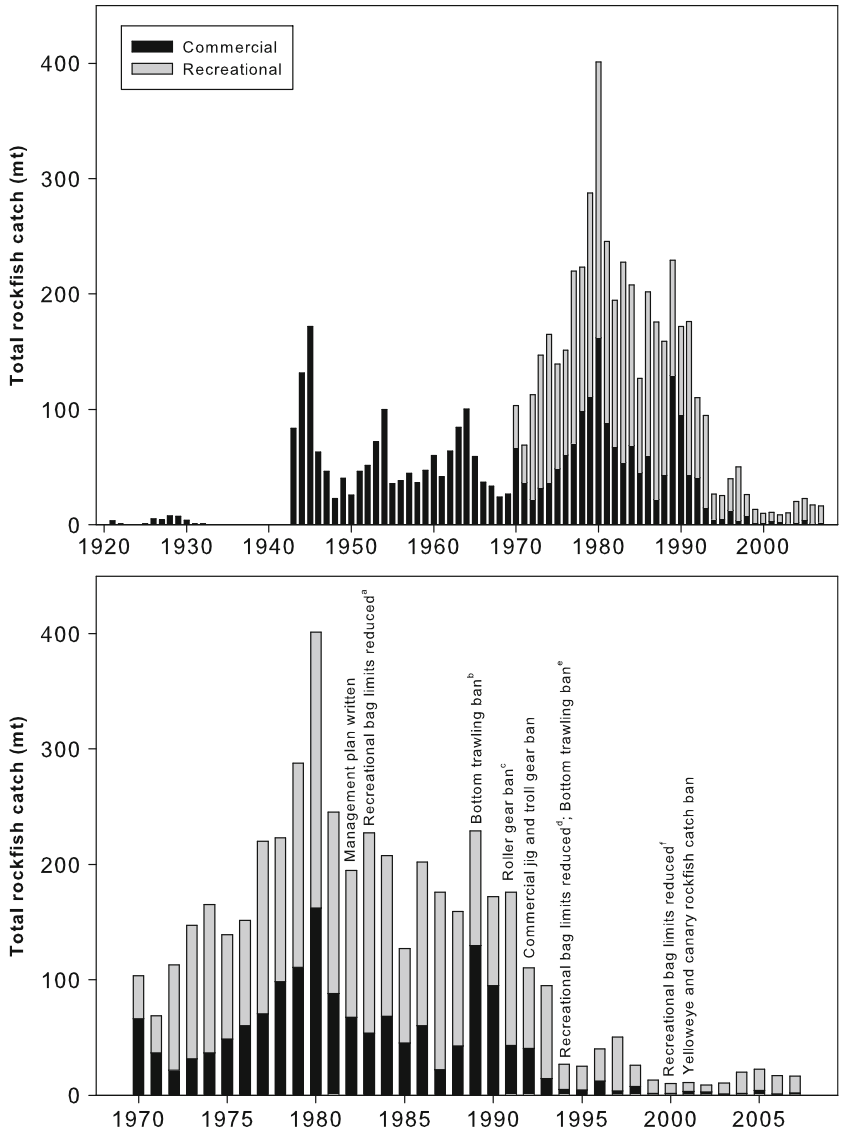


Fig. 2. (a) (top panel). Estimated or reported annual commercial and recreational catch (mt) of rockfish from Puget Sound, 1920–2007, derived from Palsson et al. [19]. Recreational rockfish data before 1970 are considered incomplete but minor; commercial rockfish catch between 1933 and 1942 is missing and/or incomplete. (b) (bottom panel). Catch data with overlay of key regulation changes 1970–2007: [a]—10 rockfish daily limit in North Sound, 5 rockfish in South Sound; [b]—south of Admiralty Inlet; [c]—all Puget Sound, effectively stopping directed trawl fisheries for rockfish and lingcod, [d]—5 rockfish daily limit in North Sound, 3 rockfish in South Sound; [e]—in Admiralty Inlet and eastern Strait of Juan de Fuca; [f]—one rockfish daily limit for all Puget Sound.

risen above 15 mt since 1993 (Fig. 2a) [19]. In part, these declines were due to more restrictive commercial regulations that limited or reduced the harvest efficiencies of some fishing practices after 1983 (Fig. 2b) [46,48,49]. Biologists had noted as early as 1961 that "the number of investigators has not kept pace with the growth of the [bottomfish] fishery" [41], and managers acknowledged that biological and fishery data, funds, and manpower were inadequate to sufficiently manage small, localized bottomfish populations, especially relative to the value of the fishery harvesting these stocks [46]. Some precautionary management strategies for rockfish were adopted and implemented by state regulators after 1983, primarily by closing directed commercial fisheries to favor recreational utilization in south Puget Sound [46,48] (Fig. 2b). However, these actions may have been too little, too late to stop population declines of species with high natural longevity and low reproductive rate, and especially so for a fishery that included rare species.

Management of rockfish stocks was further complicated because of the vexing uncertainties engendered by a mixed stock fishery without species-specific catch information or management targets [17]. "Rockfish" were aggregated as a group by the commercial fishery, likely because of the inherent similarity of many species and the irrelevance of this information to the processors and market. Furthermore, discarded rockfish bycatch was largely undocumented because commercial records only recorded landings delivered to processors. After 1970, commercial catch, effort, and value statistics were better documented in Puget Sound by sub-region, but there are still very few discrete

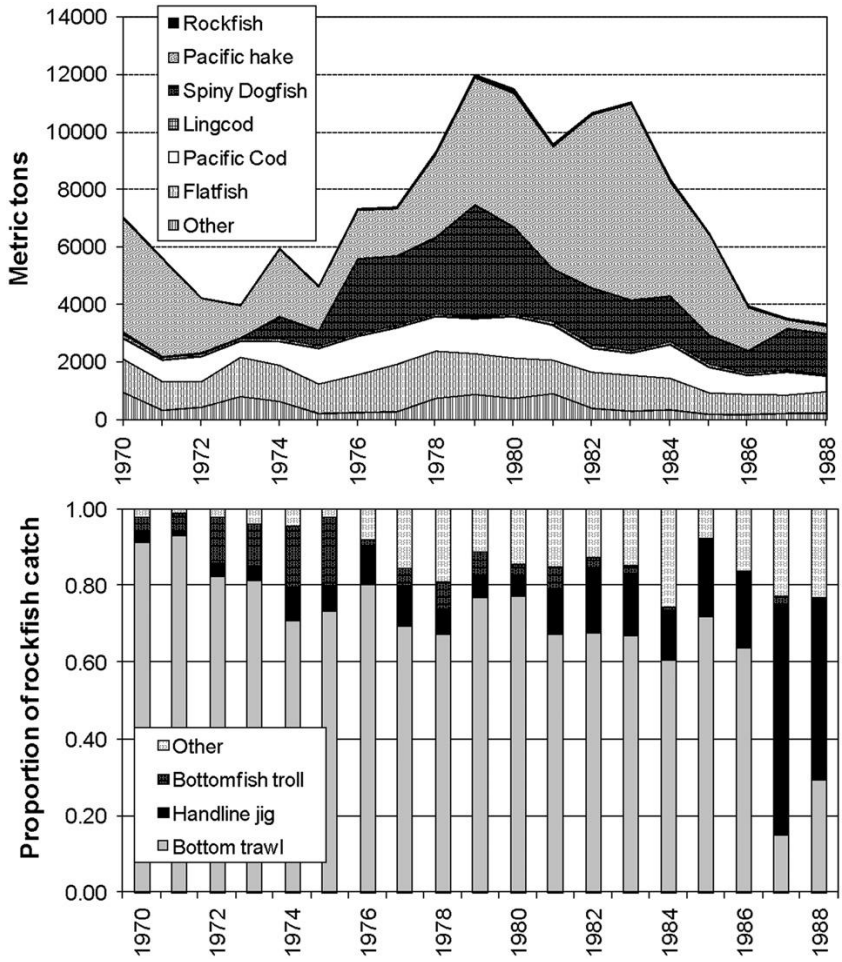


Fig. 3. (a) (top panel) Annual commercial groundfish catch (mt) from all gears by major species group, 1970–1988; data from Schmitt et al. [44]. (b) (bottom panel) Proportion of total commercial rockfish harvest (mt) by gear type, 1970–1988; data from Schmitt et al. [44].

estimates of rockfish species composition or size. For example, commercial catch information on bocaccio, yelloweye, and canary rockfish were reported from 1970 to 1988 [44], but these numbers were derived from percent composition samples made in a single year (1984) [48].

3.3. *Emerging dominance of the recreational fishery: 1970-present*

Through the mid-1960s the Washington recreational fishery and its management was consistently oriented toward Pacific salmon. In the eyes of the angler, anything less than salmon had "little prestige" and bottomfish were considered "scrap fish" [50,51]. By 1965, however, changing attitudes of marine anglers toward bottomfish were being noted by biologists, and their recreational potential was recognized, leading to the inclusion of bottomfish harvest data in recreational sampling programs. From the outset, rockfish dominated the total incidental and specific harvest of bottomfish species in most of Puget Sound [50,52,53]. As had been seen in the early trawl fishery, one attraction of this fishery was that it offered greater angler success during seasons when salmon fishing was slow, as shown by higher bottomfish retention rates in the winter and spring (Fig. 4) [50]. Bottomfish angling was expected to become more important to sport fishery

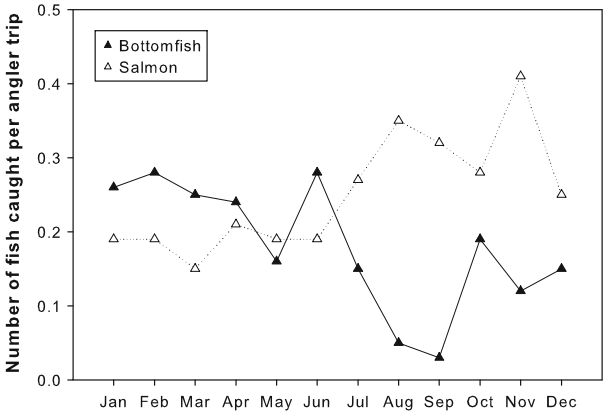


Fig. 4. Monthly catch (number of fish) per recreational angler trip for salmon and incidental bottomfish in 1965; derived from Buckley [50]. Angler trips were estimated from the boat-based, recreational salmon-sport fishery.

management in Washington State as expanding recreational demands place increased pressure on local fishery resources; these demands were already apparent by 1965 around some of

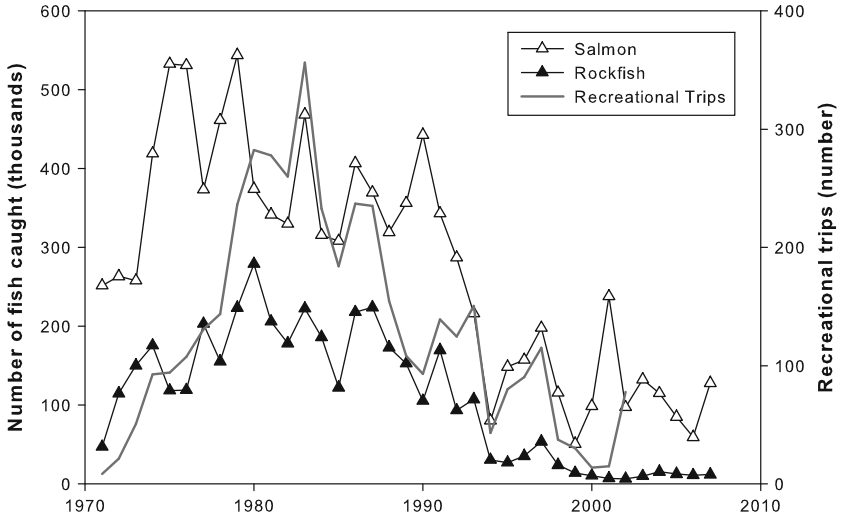


Fig. 5. Recreational catch (number of fish) and effort (boat-based angler trips targeting bottomfish) patterns for Puget Sound, 1971–2007. Data sources: rockfish catch and angler trips, Palsson et al. [19]; salmon catch, Pacific Fishery Management Council [73]. Note: rockfish harvest estimates during 1994–2003 are considered incomplete due to changes in fishing seasons.

the more densely populated metropolitan areas (Tacoma, Seattle) where large numbers of rockfish were being harvested.

Recreational anglers increasingly began to target rockfish in Puget Sound, especially as more anglers took up the sport, salmon fishing opportunities declined, and gear technology advanced. A rising nationwide interest in recreational fishing [54] was mirrored in Puget Sound by the 1970s, driven in part by technological gear advances, such as electronic depth finders, monofilament line, and new lures and fishing techniques [46,55]. Federal and state programs played a role in cultivating this demand, with rockfish and bottomfish promoted as a fun and healthy resource to catch and eat [51,56]. For example, in 1974 Washington state legislators funded a number of artificial reef and fishing pier projects designed to enhance recreational fishing opportunities [46,56], while texts and articles on bottomfish angling in Washington marine waters were being published that popularized the sport to the general public [51,57,58]. In part, popularizing bottomfishing may have been an attempt by agency managers to alleviate the expected negative social and economic effects of reduced salmon fishing opportunities for non-native fishermen after the 1974 Boldt decision [19].

Popular texts or reports also provided tips on fishing techniques and eating quality, while identifying specific Puget Sound fishing locations and habitat preferences of the larger rockfish considered "key species" by managers [51,57]. Many of these sites were in close proximity to metropolitan areas within central Puget Sound, where rocky reef habitat is relatively uncommon or occurs in isolated areas. For example, canary rockfish, which had excellent eating qualities [51], were known to occur in good numbers at certain locations as far south the Tacoma Narrows, but were considered more abundant in the San Juan Islands, north Puget Sound, and Strait of Juan de Fuca (Fig. 1). Yelloweye rockfish, also considered excellent eating [51], occurred primarily in Hood Canal, north Puget Sound, the Strait of Juan de Fuca, and the outer coast on rocky bottoms at depths over 50 m (Fig. 1). Bocaccio, only considered of "fair" eating quality due to their "grainier flesh" but nonetheless a large sport species [51], were found in localized areas characterized by steep dropoffs to 90 m [46] and frequently caught in Central Sound and the Tacoma Narrows (Fig. 1). Compilations of Puget Sound fish species distribution and relative occurrence records [51,59,60] confirm that many of these rockfish species were found in a handful of recurring locations, including Bellingham Bay, San Juan Islands, Appletree Cove (near Kingston), Hood Canal, and Tacoma Narrows/Point Defiance (Fig. 1). Smaller species, such as green-striped and redstripe rockfish, were not highly targeted by the recreational fishery and therefore were not addressed in the popular literature or management plans [46,57].

Promotion efforts helped to enhance the popularity of sport fishing throughout the region, and in turn, boosted the credibility of recreational fishing in management decisions that were historically driven by commercial fishery interests [46,48]. In fact, recreational rockfish harvest in Puget Sound typically exceeded commercial catch in each region and year since combined landings were first consistently estimated in 1970 [19]. Throughout the 1970s recreational rockfish landings in Puget Sound gradually increased, with estimates averaging over 100 mt · year^{-1} (Fig. 2a). Sport fishing trends corroborate early managers' predictions that bottomfish would serve as a recreational outlet to the rising number sport anglers; recreational fishing trips targeting bottomfish increased dramatically in the late 1970s along with total rockfish harvest, even as total salmon catch remained steady, suggesting anglers increasingly targeted or retained alternate species (Fig. 5).[1]

By the 1980s, rockfish were well-established as an important recreational and commercial species in Puget Sound and were actively managed to favor urban recreational fisheries inside of Admiralty Inlet [46,49]. Estimates of recreational landings peaked in 1980 at over 235 mt, with another peak in 1983 of almost 175 mt [19] (Fig. 2a). Managers instituted the first bag limit reductions in 1983 (Fig. 2b), but by the 1990s signs of rockfish population decline in terms of CPUE and size were evident and more reductions were put in place [19]. Harvests declined substantially during the 1990s to annual levels that averaged slightly over 50 mt; however, since 1997 recreational catches

[1] Recreational bottomfish harvest estimates between 1994 and 2003 are considered incomplete due to major changes in salmon fishing seasons that rendered the former estimation system inadequate (Palsson et al. [19]).

have not exceeded 20 mt year^{-1} (Fig. 2b). In 2000, recreational rockfish bag limits were reduced to one fish in Puget Sound and in 2001 catch prohibitions were instituted for yelloweye and canary rockfish throughout Washington's inside waters. Disregarding incomplete harvest estimates made between 1994 and 2004[1], there was a 90% decline in average annual rockfish harvest between 2004 and 2007 compared to years before 1994 [19].

Early estimates of recreational rockfish catch present a number of challenges to interpretation because surveys depended on the boat-based recreational salmon fishery, resulting in relatively low or unequal sampling effort in time and space, large increments of unidentified and possibly misidentified rockfish, and a general lack of diver, shore, and pier angler data. Although initial estimates of rockfish recreational harvest were made in 1965 [50,53], subsequent documents [19,49] do not use data before 1970 because of the survey shortcomings noted above. Recreational data provide some of the only historical information on rockfish species composition in Puget Sound, although there are also some disagreements about its validity. For example, sport catches published by Washington Department of Fisheries from 1975 to 1986 show bocaccio were harvested from south Puget Sound (punch card area 13) at rates of greater than 1000 fish year^{-1} from 1976 to 1982, including more than 7,500 bocaccio caught in 1977 [61]. In comparison, subsequent publications of the estimated bocaccio catch during the same years exceeded 1,000 bocaccio · year^{-1} only in 1977 [49]. These differences are attributed to unpublished algorithms used to correct species composition data collected before 1980, using estimates considered "more reliable" [49] from the federal Marine Recreational Fisheries Statistical Survey. WDFW rockfish species composition and catch data has been considered reliable since 2004 [19], and bocaccio are not noted as part of the recreational catch in these years. Rockfish size data from Puget Sound are similarly rare, with most records collected since 1980 via recreational creel surveys conducted by Washington Department of Fish and Wildlife (WDFW) or the federal Marine Recreational Fisheries Statistical Survey (MRFSS); older records may suffer from the same weaknesses (e.g., species misidentification) noted above.

Scientific shortcomings of the time and inadequate data, funds, and manpower almost certainly played a role in delaying management response to rockfish population declines in Puget Sound. These shortcomings are best exemplified by improvements in fish aging (otolith "break and burn" method) during the 1980s that showed rockfish were substantially older and slower-growing than had been estimated using the previous "surface-read" method [62]. Species such as yelloweye rockfish, which were formerly thought to be moderately long-lived (e.g., 20–25 years at 70 cm TL) [63] were soon recognized as ancient (80–100 years) [64]. However, by the time aging improvements were accepted by the scientific community and integrated into management, the greatest harvest of rockfish had already occurred in Puget Sound.

Furthermore, a lack of information about the distribution and availability of rockfish habitat likely influenced historical management choices. Scientists have only recently recognized that productive habitats for rockfish are much more sporadic and uncommon in southern Puget Sound than previously known [27], and comprehensive benthic habitat maps are still not widely available for much of the region. The close proximity of population centers in Seattle and Tacoma affected the magnitude of fishing pressure on these isolated rocky reef habitats, and thus, exacerbated harvest impacts in the region [52]. Such impacts would have been especially important for species like canary, bocaccio, and yelloweye rockfish that are generally associated with (and often resident upon) steep sidewalls, rocky reefs, or otherwise untrawlable bottoms (Table 1) [8].

4. Conclusions

The abundance of Puget Sound rockfishes as a group have declined about 70% over the last 40 years, with some larger species, such as bocaccio, canary rockfish, and yelloweye rockfish showing even greater declines [22]. Although a variety of factors (e.g., harvest, pollution, habitat alteration) share some blame for these declines, it is generally agreed that overfishing played a leading role, considering both the historical magnitude of the fishery removals and more recent comparisons of rockfish density and size in no-take marine protected areas to fished areas [19,22]. Indeed, such trends in Puget Sound are a microcosm of the global challenge facing stocks of fish arising from innovative and potent technology, mounting market demand, restoration of indigenous people's rights, societal need for jobs, recreation, and allocation equity [65]. Understanding and heeding the institutional, social, and economic forces that shape the use of fish populations is therefore essential as we learn to better manage marine ecosystems and the fisheries that depend on them [66].

Exploitation patterns of rockfish in Puget Sound have changed substantially over time, evolving from an opportunistic subsistence activity to a year-round focus of commercial and recreational harvest. An array of socioeconomic forces has driven these exploitation patterns, assisted by federal and state institutions that actively promoted rockfish harvests under a regulatory framework that was often slow to respond to species' declines. The demise of Puget Sound rockfish stocks may be conveniently attributed to mismanagement and lack of scientific resources. However, sustainable management has been similarly elusive in other regions [67], including the California Current where rockfish are important fishery targets and have been regulated based on a preponderance of scientific research [17,68]. Emerging examples from elsewhere reinforce the view that fisheries and ecosystem management systems succeed most often when they use the proper social and economic incentives to drive individual behavior in a way that is also considered optimal for society [67,69].

Puget Sound may also represent a model for examining the ecosystem effects of overexploiting vulnerable species, and more importantly, understanding how the ecological legacy of exploitation may constrain ecosystem recovery efforts [2]. Rockfish catch, exploitation, and regulatory policies in Puget Sound have generally presaged US Pacific Coast trends [17]; for example, bottom trawling has been banned in southern Puget Sound for the last 20 years. Fishing has been shown to disproportionately affect rockfish and other large, slower growing species with late maturation and sporadic recruitment [15,70]. Therefore, historical analysis of structural changes and trends in the rest of the Puget Sound groundfish assemblage could offer some insight into the temporal scale of ecosystem recovery after the cessation of fishing, or even reveal community phase shifts which affect recovery [71]. Undoubtedly, policy actions (and inactions) that inadvertently cause more vulnerable species to be harvested can have ultimate, but unintentional, consequences not only for those species, but also entire ecosystems [69,72].

The most intensive exploitation of reef-associated rockfish in Puget Sound was fairly short-lived (approximately 20 years, 1970–1990), yet the low intrinsic productivity of most species means that the legacy of fishing will remain for years to come. Institutions charged with restoring Puget Sound ecosystem must begin the difficult process of balancing imperfect knowledge with the need to make resource allocation decisions within a constantly changing socioeconomic environment [66]. Furthermore, they must steadily work to resolve scientific shortcomings of the past. Whether or not the scientific and management community of Puget Sound can rise to the challenge remains to be

seen. To paraphrase Norman Cousins, the history of rockfish exploitation in Puget Sound serves as a "vast early warning system", and it is clear we would do well to heed the lessons of the past.

Acknowledgments

Thanks to Aaron Dufault, who ably assisted in many aspects of literature review, acquisition, and data entry. We are grateful to WDFW biologists Ray Buckley, Greg Bargmann, Debbra Bacon, and Greg Lippert for sharing literature, photographs, and insight into historic fisheries. Robert Kopperl of Northwest Archaeological Associates, Inc. and Laura Phillips from the University of Washington's Burke Museum greatly improved our understanding of the zooarchaeological literature and the study of fish bones. Thanks to Carolyn Marr and the Seattle Museum of History and Industry for access to photography archives, and specifically, Karl House of the Puget Sound Maritime Historical Society who sorted through photographs and provided his time and guidance. Craig Wilson, NWFSC librarian, somehow always produced obscure documents that we thought to be unobtainable. Discussions with and reviews by Anne Beaudreau, Chris Harvey, and Ray Buckley greatly improved the manuscript. This manuscript emerged as an outgrowth of the biological review team's (BRT) 2009 examination of historical catch data for rockfish proposed for ESA listing in Puget Sound.

References

[1] Hayashida FM. Archaeology, ecological history, and conservation. Annual Review of Anthropology 2005;34:43–65.
[2] Foster D, Swanson F, Aber J, Burke I, Brokaw N, Tilman D, et al. The importance of land-use legacies to ecology and conservation. Bioscience 2003;53:77–88.
[3] Pitcher TJ. Fisheries managed to rebuild ecosystems? Reconstructing the past to salvage the future Ecological Applications 2001;11:601–17.
[4] Rosenberg AA, Bolster WJ, Alexander KE, Leavenworth WB, Cooper AB, McKenzie MG. The history of ocean resources: modeling cod biomass using historical records. Frontiers in Ecology and the Environment 2005;3:78–84.
[5] Musick JA. Ecology and conservation of long-lived marine animals. In: Musick JA, editor. Life in the slow lane: ecology and conservation of longlived marine animals. Symposium 23. Bethesda, Maryland: American Fisheries Society; 1999. p. 1–10.
[6] Crouse DT. The consequences of delayed maturity in a human-dominated world. In: Musick JA, editor. Life in the slow lane. Ecology and conservation of long-lived marine animals. Bethesda, Maryland: American Fisheries Society; 1999. p. 195–202.
[7] Kendall AW. Systematics and identification of larvae and juveniles of the genus *Sebastes*. Environmental Biology of Fishes 1991;30:173–90.
[8] Love MS, Yoklavich MM, Thorsteinson L. The rockfishes of the Northeast Pacific. Berkeley, California: University of California Press; 2002.
[9] Tolimieri N, Levin PS. The roles of fishing and climate in the population dynamics of bocaccio rockfish. Ecological Applications 2005;15:458–68.
[10] Moser HG, Boehlert GW. Ecology of pelagic larvae and juveniles of the genus *Sebastes*. Environmental Biology of Fishes 1991;30:203–24.
[11] Ralston S, Howard DF. On the development of year-class strength and cohort variability in two northern California rockfishes. Fishery Bulletin 1995;93:710–20.
[12] Tolimieri N, Andrews KA, Williams GD, Katz SL, Levin PS. Home range size and patterns of space use by lingcod, copper rockfish, and quillback rockfish in relation to diel and tidal cycles. Marine Ecology Progress Series 2009;380:229–43.
[13] Gunderson DR, Vetter RD. Temperate rocky reef fishes. In: Kritzer JP, Sale PF, editors. Marine metapopulations. San Diego, CA: Academic Press; 2006. p. 69–117.
[14] Mangel M, Levin P, Patil A. Using life history and persistence criteria to prioritize habitats for management and conservation. Ecological Applications 2006;16:797–806.
[15] Levin PS, Holmes EE, Piner KR, Harvey CJ. Shifts in a Pacific Ocean fish assemblage: the potential influence of exploitation. Conservation Biology 2006;20:1181–90.
[16] Harvey CJ, Tolimieri N, Levin PS. Changes in body size, abundance, and energy allocation in rockfish assemblages of the Northeast Pacific. Ecological Applications 2006;16:1502–15.
[17] Parker SJ, Berkeley SA, Golden JT, Gunderson DR, Heifetz J, Hixon MA, et al. Management of Pacific rockfish. Fisheries 2000;25:22–30.
[18] PFMC. Pacific coast groundfish fishery management plan, for the California, Oregon, and Washington groundfish fishery, as amended through Amendment 19. Pacific Fishery Management Council, Portland, Oregon, 2008.
[19] Palsson WA, Tsou T, Bargmann GG, Buckley RM, West JE, Mills ML, et al. The biology and assessment of rockfishes in Puget Sound. Washington Department of Fish and Wildlife, FPT 09-04, Olympia, WA, 2009.
[20] NMFS. Federal Register Docket No. 990614161-9161-01, 21 June 1999. 64, 1999.
[21] Stout HA, McCain BB, Vetter RD, Builder TL, Lenarz WH, Johnson LL, et al. Status review of copper rockfish, quillback rockfish, and brown rockfish in Puget Sound, Washington. US Department of Commerce, NOAA Technical Memo. NMFS-NWFSC- 46, 2001.
[22] NMFS. Preliminary scientific conclusions of the review of the status of 5 species of rockfish: bocaccio (*Sebastes paucispinis*), canary rockfish (*Sebastes pinniger*), yelloweye rockfish (*Sebastes ruberrimus*), greenstriped rockfish (*Sebastes elongatus*) and redstripe rockfish (*Sebastes proriger*) in Puget Sound, Washington. National Marine Fisheries Service. Available at 〈http://www.nwr.noaa.gov/Other-Marine-Species/Puget-Sound-Marine-Fishes/upload/PS-rockfish-review-08.pdf〉, 2008.
[23] NMFS. Federal Register 74(77):18516-18542. 74, 2009.
[24] Burns R. The shape and form of Puget Sound. Seattle, WA: Washington Sea Grant Program; 1985.
[25] Thomson RE. Physical oceanography of the Strait of Georgia-Puget Sound-Juan de Fuca Strait System. In: Wilson RCH, Beamish RJ, Aitkens F, Bell J, editors. Review of the marine environment and biota of Strait of Georgia, Puget Sound, and Juan de Fuca Strait: Proceedings of the BC/Washington symposium on the marine environment, 1948, 36–98 pp, Canadian Technical Report of Fisheries and Aquatic Sciences, 1994.
[26] NMFS. Sound science. In: Ruckelshaus MH, McClure MM, editors. Synthesizing ecological and socioeconomic information about the Puget Sound ecosystem. US Department. of Commerce, National Oceanic and Atmospheric Administration, National Marine Fisheries Service (NMFS), Northwest Fisheries Science Center, Seattle, Washington, 2007.
[27] Pacunski RE, Palsson WA. The distribution and abundance of nearshore rocky-reef habitats and fishes in Puget Sound. In: Strickland RM, editor. Puget sound research conference proceedings, Puget Sound Water Quality Action Team, Olympia, Washington, 1998.
[28] Ebbesmeyer CC, Barnes CA. Control of a fjord basin's dynamics by tidal mixing in embracing sill zones. Estuarine and Coastal Marine Science 1980;11:311–30.
[29] Strickland RM. The fertile fjord: plankton in Puget Sound. Seattle: University of Washington Press; 1983.
[30] Suttles WP. Economic life of the coast Salish of Haro and Rosario Straits. Ph.D. dissertation, University of Washington, Seattle, WA, 1951.
[31] McKechnie I. Investigating the complexities of sustainable fishing at a prehistoric village on western Vancouver Island, British Columbia, Canada. Journal for Nature Conservation 2007;15:208–22.
[32] Stewart H. Indian fishing. Early methods on the Northwest Coast. Seattle, Washington: University of Washington Press; 1977.
[33] Butler VL, Campbell SK. Resource intensification and resource depression in the Pacific Northwest of North America: A zooarchaeological review. Journal of World Prehistory 2004;18:327–405.
[34] Kopperl RE. Analysis of fish remains, Watmough Bay site stabilization project. Appendix B in Watmough Bay site stabilization project, 45-SJ-280. In: Phillips L, Stein J, editors. Bone analysis summary and reports, Submitted to Bureau of Land Management, Spokane, Washington, 2007.
[35] Kopperl RE. Fish remains from middens in Garrison Bay, San Juan Island, WA. In Stein JK, Taylor AK, Kessler RA, editor. Is it a House? Interpreting a shell midden on San Juan Island, Washington. University of Washington Press, Seattle, WA, 2010.
[36] Kopperl RE, Butler V. Faunal analysis: fish remains. In: Stein JK, Phillips LS, editor. Vashon Island archaeology: a view from Burton Acres shell midden. 105–118 pp, Burke Museum of Natural History and Culture Research Report No. 8, University of Washington Press, Seattle, 2002.
[37] Rathbun R. A review of the fisheries in the contiguous waters of the state of Washington and British Columbia. In: Bowers, GM, Commissioner. United States Commission of Fish and Fisheries. Report of the Commissioner for the year ending June 30, 1899, 332 pp, United States government printing office, 1900.
[38] Jordan DS, Starks EC. The fishes of Puget Sound. Proceedings of the California Academy of Sciences 1895;5:785–855.
[39] Kincaid T. An annotated list of the Puget Sound fishes. State of Washington, Department of Fisheries, 1919.
[40] Heyamoto H, Holmberg EK, DiDonato GS. Research report on the Washington trawl fishery, 1957–1959. State of Washington, Department of Fisheries, Research Division, 1959.
[41] Holmberg EK, DiDonato GS, Pasquale N. Research report on the Washington trawl fishery, 1960–1961. State of Washington, Department of Fisheries, Research Division, 1961.
[42] Holmberg EK, Day D, Pasquale N, Pattie B. Research report on the Washington trawl fishery 1962–1964. State of Washington, Department of Fisheries, Research Division, 1967.
[43] Smith RT. Report on the Puget Sound otter trawl investigations. Biological report no. 36B. Department of Fisheries, State of Washington, 1936.

[44] Schmitt C, Quinnell S, Rickey M, Stanley M. Groundfish statistics from commercial fisheries in Puget Sound, 1970–1988. WDFW progress report no. 285, 1991.
[45] Levin PL, Dufault A. Eating up the food web. Fish and Fisheries 2010:1–6, doi:10.1111/j.1467-2979.2010.00355.x.
[46] Pedersen MG, DiDonato G. Groundfish management plan for Washington's inside waters. Progress report no. 170. State of Washington, Department of Fisheries, 1982.
[47] Seattle PD. Seattle 1990: Who we are. In Current planning research bulletin number 52, City of Seattle, Seattle Planning Department, Seattle, Washington, 1992.
[48] Pedersen MG, Bargmann GG. 1984 supplement for the groundfish management plan for Washington's inside waters. Progress report no. 247. Washington Department of Fisheries 1986.
[49] Palsson WA. Bottomfish catch and effort statistics from boat-based recreational fisheries in Puget Sound, 1970–1985. State of Washington, Department of Fisheries, Olympia, WA, 1987.
[50] Buckley RM. 1965 bottomfish sport fishery. Supplemental progress report. Washington Department of Fisheries, 1967.
[51] Washington PM. Recreationally important marine fishes of Puget Sound, Washington. In NWAFC processed report, 60, Northwest and Alaska Fisheries Center, National Marine Fisheries Service, Seattle, WA, 1977.
[52] Buckley RM. 1967 bottomfish sport fishery. In supplemental progress report, WA Department of Fisheries, 1970.
[53] Bargmann GG. The recreational hook and line fishery for marine fish in Puget Sound, 1968–1973. Washington Department of Fish and Wildlife, progress report no. 33, 1977.
[54] Coleman FC, Figueira WF, Ueland JS, Crowder LB. The impact of United States recreational fisheries on marine fish populations. Science 2004;305:1958–60.
[55] Cooke SJ, Cowx IG. Contrasting recreational and commercial fishing: searching for common issues to promote unified conservation of fisheries resources and aquatic environments. Biological Conservation 2006;128:93–108.
[56] Buckley RM. Marine habitat enhancement and urban recreational fishing in Washington. Marine Fisheries Review 1982;44:28–37.
[57] Haw F, Buckley R. Saltwater fishing in Washington. Seattle, WA: Stanley N. Jones; 1971.
[58] Washington PM. Selected reprints on angling for Puget Sound bottom fishes. In: Washington PM, editor. NWAFC processed report. Northwest and Alaska Fisheries Center, National Marine Fisheries Service, Seattle, WA, 1977.
[59] Miller BS, Borton SF. Geographical distribution of Puget Sound fishes: maps and data source sheets. University of Washington, Fisheries Research Institute, vol. 3, Seattle, 1980.
[60] Delacy AC, Miller BS, Borton SF. Checklist of Puget Sound fishes. Washington Sea Grant Program Publication WSG 72-3, 1972.
[61] Hoines LJ, Ward WD. Washington state sport catch report, 1985. Washington State Department of Fisheries, 1985.
[62] Chilton DE, Beamish RJ. Age determination methods for fishes studied by the groundfish program at the Pacific Biological Station. In Canadian Special Publications, Fisheries and Aquatic Sciences, 60, Fish and Oceans, Canada, 1982.
[63] Washington PM, Gowan R, Ito DH. A biological report on eight species of rockfish (*Sebastes* spp.) from Puget Sound, Washington. In NWAFC processed report, Northwest and Alaska Fisheries Center, National Marine Fisheries Service, Seattle, 1978.
[64] Yamanaka KL, Lacko LC, Withler R, Grandin C, Lochead JK, Martin JC, et al. A review of yelloweye rockfish *Sebastes ruberrimus* along the Pacific coast of Canada: biology, distribution, and abundance trends. In Canadian Science Advisory Secretariat, 2006.
[65] Pitcher T. Back-to-the-future: a fresh policy initiative for fisheries and restoration ecology for ocean ecosystems. Philosophical Transactions of the Royal Society B: Biological Sciences 2005;360:107–21.
[66] Hughes TP, Bellwood DR, Folke C, Steneck RS, Wilson J. New paradigms for supporting the resilience of marine ecosystems. Trends in Ecology & Evolution 2005;20:380–6.
[67] Hilborn R, Punt AE, Orensanz J. Beyond band-aids in fisheries management: fixing world fisheries. Bulletin of Marine Science 2004;74:493–507.
[68] Ralston S. The status of federally managed rockfish on the US west coast. In: Yoklavich MM, editor. Marine harvest refugia for west coast rockfish: a workshop. US Department of Commerce, 1998.
[69] Botsford LW, Castilla JC, Peterson CH. The management of fisheries and marine ecosystems. Science 1997;277:509–15.
[70] Jennings S, Greenstreet SPR, Reynolds JD. Structural change in an exploited fish community: a consequence of differential fishing effects on species with contrasting life histories. Journal of Animal Ecology 1999;68: 617–627.
[71] Mangel M, Levin PS. Regime, phase and paradigm shifts: making community ecology the basic science for fisheries. Philosophical Transactions of the Royal Society B-Biological Sciences 2005;360:95–105.
[72] Jackson JBC, Kirby MX, Berger WH, Bjorndal KA, Botsford LW, Bourque BJ, et al. Historical overfishing and the recent collapse of coastal ecosystems. Science 2001;293:629–38.
[73] Pacific Fishery Management Council. Review of 2008 ocean salmon fisheries. Pacific Fishery Management Council, Portland, Oregon, 2009.