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