lingcod diet increases by three-fold for lingcod found inside marine reserves (Beaudreau and Essington 2007). Preliminary observations (B. Brown, Moss Landing Marine Laboratories, personal communication, 6 April 2017) from lingcod stomachs contents sampled from Washington to California in both nearshore and offshore habitats indicate a higher occurrence of bony fishes from Washington and Oregon waters, and a higher occurrence of cephalopods in lingcod from California waters with an overlapping region near southern Oregon. This latitudinal shift in prey composition suggests differences in feeding behavior and the predatory role of lingcod in coastal environments.

Map

Figure 1a shows the geographic scope of the assessment and depicts boundaries for fisheries and data collection strata. The stock assessment is split into two areas, north and south of the California border.

Historical and current fishery

Lingcod fisheries have a long history, with the earliest evidence of lingcod fishing coming from the remains of 51 archaeological sites representing the period between 6200 BC and 1830 AD on the central California coast from San Mateo to San Luis Obispo (Gobalet and Jones 1995). More recently, the commercial fishery off of California dates back more than a century, and the fishery off of Washington and Oregon dates back nearly as far. Recorded commercial and recreational take of lingcod began during the 1920s in southern California, then Oregon and Washington later during the 1940s.

Lingcod are harvested commercially by trawl and longline gear, and recreationally by hook-and-line and spear (see executive summary figures a and b). The fishery steadily grew with the rise of the groundfish trawl industry, reaching peak landings during in the early 1980s. Landings decreased during the late 1980s due to population declines and the implementation of seasonal closures and size limits. During 1999 the lingcod fishery was declared overfished coast-wide. With the combination of a federal rebuilding plan implemented during 2003 and favorable ocean conditions for lingcod recruitment, the population was deemed recovered in 2005, four years ahead of the projected recovery time.

In California, the recreational lingcod fishery has substantial landings that have surpassed that of the CA commercial fleet since 1998. At the peak of the lingcod fishery during 1974, the landings were nearly equally divided between the commercial and recreational fleets. From 1980 to 2008, 95% to 97% of lingcod caught were taken by boat-based anglers (commercial passenger fishing vessel, CPFV, and private/rental boats). Private boat landings (including kayaks) were higher than those from CPFVs. A small fraction of landings are from spear fishers using SCUBA or free diving gear (Lynn 2008).

Catches of lingcod in Oregon and Washington have shifted from the commercial trawl fleet, accounting for 90% of landings during its mid-1980s peak, to a fishery evenly split between commercial and recreational in recent years. Between 1980 and 1996, the majority of lingcod were caught by the bottom trawl fishery (>75%), followed by troll and hook-and-line (between 10-20%), with a small fraction of additional landings from pots and traps, nets, and shrimp trawls (Jagielo et al. 1997). From 1999 to 2016, however, the recreational fishery has contributed about half of all lingcod landings, on average.

Management history and performance

Prior to 1977, lingcod stocks in the northeast Pacific were managed by the Canadian Government within its waters, and by the individual states in waters (out to three miles) off of the United States. With implementation

of the Magnuson-Stevens Fishery Conservation and Management Act (MSA) in 1976, primary responsibility for management of the groundfish stocks off Washington, Oregon and California shifted from the states to the Pacific Fishery Management Council (PFMC). The U.S. west coast allowable biological catch (ABC) for lingcod was set at 7,000 mt, but catch was consistently below this level. In 1994, a harvest guideline (HG) of 4,000 mt was set. In 1995, both the ABC and HG were dropped to 2,400 mt based on a quantitative assessment (Jagielo et al. 2000). Trip limits on commercial Lingcod catch were first instituted in 1995, when a 20,000 lbs. /month limit was imposed, and a minimum size was imposed for recreational fisheries of 22 inches. During 1998 to present, individual year ABC and OY levels were set, commercial trip limits became much more restrictive (starting at 1,000 mt/2 months in 1998), and recreational bag limit were set at 2 (or 1) lingcod with minimum sizes ranging from 22 to 30 inches.

PFMC implemented an initial Lingcod Rebuilding Plan in 2000 with size and seasonal limitations in the recreational fishery and a change to limited entry and open access sectors in the commercial fishery. The coast-wide ABC was further reduced by 27.1% (700 mt, down from 960 mt). In the commercial fishery sector, harvest guidelines in 2000 were reduced by over 80% from 1998 limits. In order to achieve these low harvest goals, all commercial fishing for lingcod was closed for six months (January to April, and November to December). During the open period between April and November, all commercial vessels were limited to 400 pounds per month, and lingcod landed by non-trawl vessels south of Cape Mendocino had a minimum size limits of 26 inches long, and 24 inches long in all other areas. During the rebuilding period between 2000 and 2005, cumulative trip limits were very low at 800 pounds for every 2 months with frequent closures.

After 2006, the population had rebuilt, and the ABC and trip limits began rising, with a bimonthly limit of 1,200 pounds. Concurrently, Marine Protected Areas (MPAs) in California, Rockfish Conservation Area (RCA) and Cowcod Conservation Area (CCA) were implemented, prohibiting take of all groundfish within specified depths, habitats, and locations.

During 2011, the limited entry trawl sector became a catch share program with 100% observer coverage, while during the period 2002 to 2011 observed trips were chosen by random stratified sampling. The Trawl Catch Share Program requires 100% at-sea observer coverage since all catch of Individual Fishing Quota (IFQ) species must be accounted for to allow fishers and managers to track and monitor their individual quotas.

The first recreational regulations for lingcod were set in 1994, with a bag limit of 3 fish in Washington and Oregon, 5 fish in California, and coast-wide size limit of 22 inches. In 1998, the bag limit in all three states dropped to 2 fish per day at 24 inches, where it largely remained until 2008. Regulations in California fluctuate frequently, where during the stock rebuilding period between 2000 and 2004 the California recreational bag limit dropped to 1 fish per day, and the size limit increased from 26 inches to 30 inches. In 2015, the bag limit was increased to 3 fish per day in California, 2 fish per day in Oregon and Washington, and a size limit of 22 inches. Most recently, the bag limit in California has decreased back to 2 fish per day.

Summaries of regulatory histories for both federal and state management actions are available as supplementary materials to this stock assessment. See table k in the executive summary for a recent history of OFLs, ACLs, landings, and catch (landings plus discards) for each area.

Fisheries off of Alaska, Canada, and Mexico

Lingcod fisheries in the Gulf of Alaska are managed in state waters by the State of Alaska Board of Fisheries and in federal waters by the North Pacific Management Council. The sport fishery is restricted by daily bag and

possession limits. Commercial fisheries are restricted by catch and bycatch quotas. Lingcod are a non-target species in the subsistence fishery. No formal lingcod stock assessment has been done in Alaskan waters.

Lingcod in Canada are managed under the Pacific Integrated Goundfish Fishery by the Department of Fisheries and Oceans for take by First Nations and the commercial and recreational sectors. Beginning in 1997, the Canadian commercial groundfish trawl fishery implemented an IVQ (Individual vessel quota) program that now incorporates all commercially caught trawl and hook and line groundfish. Stocks in distinct management areas are regularly assessed, with the most recent lingcod assessment in outer British Columbia waters in 2011, and in the Strait of Georgia in 2014 (DFO, 2016). The 2011 assessment implements a Bayesian surplus production model to assess lingcod stock status within four assessment areas. Overall the stock appears to have remained stable from 1927-1970, declined until 1980, increased until 1990 and has continued to decline since then. However the stock is still estimate to be healthy with respect to reference points. The 2016 assessment implement a two-sex statistical catch-at-age model in a Bayesian model. Results suggest that spawning biomass in 2014 is greater than spawning biomass at the start of the current management regime during 2006, and that the stock is likely in a precautionary management zone.

Southern CA recreational fishers have reported fishing in Mexican waters and landing fish in U.S. ports. This is an issue that requires further investigation. There are no known Mexican stock assessments for lingcod.

2. Data

The following sources of data were used in building this assessment, which is partitioned into two independent assessment areas: a northern area for WA and OR and a southern area for CA:

1. Fishery independent data including bottom trawl survey-based indices of abundance and biological data (age and length) from the NWFSC survey and AFSC Triennial survey.
2. Research length and age composition data from WDFW (north model only) and L. Lam (pers. Comm.)
3. Estimates of fecundity, maturity, length-weight relationships and ageing error from various sources.
4. Commercial landings, length, and age composition data.
5. Estimates of commercial discard length frequencies and fraction discarded in the fishery obtained from the West Coast Groundfish Observer Program (WCGOP).
6. Recreational landings, length, and age composition data.
7. Commercial and recreational fishery CPUE.

Data availability by source and year is presented in Figures 2 and 3 as well as in the more detailed data sections below. A description of each of the specific data sources follows.

Fishery Independent Data: NWFSC WCGBTS trawl survey

Three sources of information are produced from the West Coast Groundfish Bottom Trawl Survey (WCGBTS): an index of relative abundance, length-frequency distributions, and age-frequency distributions. Only years in which this survey included the continental shelf are considered (2003 forward), since lingcod are primarily a shelf species.

The WCGBTS is based on a random-grid design, covering the coastal waters from a depth of 55 m to 1,280 m (Keller et al. 2007). This design uses four industry chartered vessels per year, assigned to a roughly equal number of randomly selected grid cells and divided into two ‘passes’ of the coast that are executed from north to south. Two vessels fish during each pass, and survey tows are conducted from late May to early October each year. This design therefore incorporates both vessel-to-vessel differences in catchability as well as variance