Regional Studies in Marine Science 56 (2022) 102708

Contents lists available at ScienceDirect

Regional Studies in Marine Science

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

Balancing the asymmetry of knowledge of the transboundary white seabass (*Atractoscion nobilis*) fishery resource: Landings reconstruction along the west coast of the Baja California Peninsula

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ARTICLE INFO

Article history:
Received 14 June 2022
Received in revised form 26 September 2022
Accepted 17 October 2022
Available online 23 October 2022

Keywords:
Historical data reconstruction
White seabass
Transboundary fishery resource
Small-scale fishery
Medium-scale fishery
Stock structure

ABSTRACT

The white seabass (*Atractoscion nobilis*) is an important transboundary fishery resource exploited by the U.S. and Mexico. White seabass commercial landing estimates for the past 100 years have formed the basis of U.S. management regulations. However, species-specific landing records for white seabass are unavailable for Mexico and management efforts based on fishery trends are not possible. To better document the Mexican harvest of white seabass and the factors contributing to annual landing trends in the commercial fishery, we used a six-step process to reconstruct white seabass harvest along the west coast of the Baja California Peninsula from 1949 to 2019. Although historical records obtained from Mexican Fisheries Statistics Year Books and those from Official Catch Landings Reports do not directly align. Both data sources show that overall Mexican white seabass landings has increased over the last 30 years with disparate regional trends. The increase is largely from the small-scale gillnet fleet of Baja California Sur, which accounts for more than 97% of the total catch. Based on the Official Catch Landings Reports, estimated landings show a large increase (228%) over the past 20 years. The landings reconstruction estimates provide baseline information that can be used to better manage and monitor the white seabass in Mexico. Further, given the transboundary nature of the resource, these data may help establish the information needed to explore co-management efforts with the U.S. This work highlights the value of the white seabass to the fisheries off Baja California and supports the need for the continued collection of new and accurate information on catch levels, fishing effort, and stock structure of this transboundary resource.

1. Introduction

Catch data play a critical role in fisheries management as they are used to inform stock assessments and determine the harvest volume that may be sustainably extracted from a system (Pauly, 1998; Pauly et al., 2013). Moreover, historical catch data contribute to a better understanding of the current fishery status and how it has changed over time (Mcclenachan et al., 2012a; Pauly et al., 2005). In many developing countries, catch time-series data are either unavailable or unreliable. For species with a geographic distribution that extends across international boundaries, data asymmetry (i.e., bias in the availability of information over the full range of a fishery) between countries may complicate national or international management, mislead stock assessment outcomes, and impact the effectiveness of management policies (Cisneros-Montemayor et al., 2020; Ishimura et al., 2013; Ramírez-Valdez et al., 2021).

White seabass (WSB, *Atractoscion nobilis*) range from the Gulf of California to Alaska in the northeastern Pacific, where it is considered a transboundary fishery resource exploited by both Mexico and the U.S. (Cartamil et al., 2011; Cota-Nieto et al., 2015; Ojeda-Ruiz et al., 2018; Thomas, 1968; Valero and Waterhouse, 2016). Nearly all of the U.S. landings are from California, harvested by hook and line, drift net, and set net gear types, in addition to the presence of a large recreational fleet (CDFG, 2020a; Valero and Waterhouse, 2016). The California commercial fishery has harvested WSB for over 100 years, both in U.S. and Mexican waters until 1982, when the Mexican government prohibited foreign commercial fleets from fishing within national waters (Vojkovich and Reed, 1983). California WSB landings have fluctuated over time, reaching their highest level in 1959 with almost 1600 metric tons (mt) and their lowest in 1997 with less

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https://doi.org/10.1016/j.rsma.2022.102708

than 30 mt (Valero and Waterhouse, 2016). Since 1931, California state managers have enacted several fishery regulations to counteract declining harvest trends, including a minimum size limit of 71 cm in total length, bag limit reductions, gear restrictions, and a fishing seasonal ban for commercial purposes (March 15–June 15) during a portion of the spawning season (CDFG, 2002; (Valero and Waterhouse, 2016; Vojkovich and Reed, 1983). In 2016, the first modern statistically integrated stock assessment was conducted for California WSB, which estimated the stock status and spawning biomass trends (Valero and Waterhouse, 2016). The 2016 assessment showed a steady decline in California landings since 2008, from ∼300 mt to ∼70 mt in 2014. However, according to the California State guidelines, the WSB stock is not experiencing overfishing (CDFG, 2020b). Nonetheless, this assessment did not incorporate landings data from neighboring fisheries in Mexico.

In Mexico, the WSB is considered a seasonal target species along the west coast of the Baja California Peninsula and within the upper Gulf of California (Cartamil et al., 2011; Cota-Nieto et al., 2018; Escobedo-Olvera, 2009; Ojeda-Ruiz et al., 2018). Although fisheries exist within the northern Gulf of California, there is limited information on the effort and harvest of WSB in this region, and genetically, it is thought to be distinct from the Pacific coast stock(s) (Franklin et al., 2016). White seabass population connectivity along the Pacific coast remains uncertain, and there is debate over whether there are one or two stocks in the region. Early studies suggested that California and the west coast of the Baja California Peninsula share the same breeding stock (Ríos-Medina, 2008). Other studies have proposed a two-stock hypothesis across the west coast distribution, based on genetic analyses (Franklin et al., 2016), otolith microchemistry (Romo-Curiel et al., 2016), and distinct growth rates (Romo-Curiel et al., 2015) between WSB within northern (California and Baja California) and southern regions (Baja California Sur). In support of the two-stock hypothesis, tagging studies have documented northerly and southerly movements across the U.S. and Mexico border, with limited movement from the northern range into the southern fishing areas below Punta Eugenia (Aalbers and Sepulveda, 2015; Aalbers et al., 2021).

In further support of the two-stock hypothesis, the Baja California Peninsula (BCP) encompasses the southern portion of the California Current System (McClatchie, 2014; Durazo, 2015), which has a geographic break around Punta Eugenia (Ibarra-Obando et al., 2001, Fig. 1). This break occurs near the middle of the BCP, proximal to the border between Baja California (BC) and Baja California Sur (BCS), the two Mexican states with the largest WSB production in the country (Escobedo-Olvera, 2009; Ojeda-Ruiz et al., 2018). The prominent landmass around Punta Eugenia produces two distinct biogeographic provinces characterized by differences in seasonal oceanographic features and represents the distribution boundary for several fish taxa common to the San Diegan and the tropical Panamic provinces (Quast, 1968; Durazo et al., 2010; Durazo, 2015; Ramírez-Valdez et al., 2015). In summer and autumn, the separation of these two biogeographic provinces is evident due to differences in the sea surface layer. The influence of subarctic waters characterizes the northern region, where high oxygen content, lower salinity, and upwellings are persistent (Durazo et al., 2010). The southern region has two climatic regimes, characterized by the presence of subtropical and tropical surface waters during the summer and fall months (warm regime) and the strengthening in the intensity of seasonal winds and coastal upwelling events during the winter and springtime (cold regime) (Durazo et al., 2010). Seasonal differences in oceanographic conditions have been suggested to explain the distinctions in early life growth rates and otolith isotopic composition among WSB sampled from north and south of Punta Eugenia (Romo-Curiel et al., 2015) as well as a boundary among WSB populations studied in the region (Franklin et al., 2016).

In addition to uncertainties in the WSB stock structure, catch records from the commercial fishery remain unavailable throughout Mexico. Currently, catches of WSB are aggregated into a sciaenid-species complex called 'Corvina,' which includes other croakers such as *Cynoscion parvipinnis, Cynoscion xanthalus,* and *Cynoscion othonopterus* (Secretaría de Agricultura y Desarrollo Rural (SADER), 2018). In Mexico, the Corvina fishery does not have any species-specific management regulations such as size, effort limits, or landing quotas, and it is regulated only through non-species-specific fishing permits (Secretaría de Agricultura y Desarrollo Rural (SADER), 2018). Therefore, baseline information on effort and catch is necessary, including species-specific landings trends over time, to develop effective management regulations for WSB fishery in Mexico. These data are critical for better understanding the current stock status and how it has changed in response to exploitation (Mcclenachan et al., 2012a).

Considering the importance of the WSB resource and the lack of available fishery information, the objective of this study was to compile and analyze historical WSB landings in Mexico. We incorporated methods modified from a general procedure used to reconstruct historical landings for other data-limited fisheries (Pauly and Zeller, 2016a). Based on a thorough literature search and the use of alternative data sources (i.e., official reports, and fisher interviews), we reconstructed WSB landing estimates for Mexican fisheries from 1949 through 2019. White seabass landings reconstruction trends were associated with historical and contextual factors. This study also incorporates more recent (2000–2019) and detailed fishery statistics from Official Catch Landings Reports (OCLRs) to assess seasonal and state-wide landings (BC and BCS), as well as preliminary estimates of catch per unit effort (CPUE). Based on the potential for more than a single WSB stock along the Pacific coast, analyses were also performed to compare regional differences between the two Mexican states.

2. Methods

2.1. Study area

This study focused primarily on the small-scale and medium-scale fisheries that occur along the BCP west coast, extending from the U.S. border to the southern tip of Baja California. Fisheries inside the Gulf of California are not considered in this study. The BCP is a relatively rural landscape with only two major ports for the medium-scale fishery, one in the north (Ensenada, BC) and the other in the south (San Carlos, BCS). The remainder of the fishing hubs are dispersed along the peninsula from relatively small fishing camps (fewer than 8 vessels) that require beach launching and the use of smaller platforms. A total of 104 fishing camps have been registered, of which 44 are in BC and the rest are in BCS. Many of these fishing camps are rustic seasonal establishments with no electricity or permanent structures. Meanwhile, in smaller numbers, other regional fishing camps occur within more established towns with permanent infrastructure and organized fishing cooperatives (Cartamil et al., 2011; Ramirez-Amaro et al., 2013). Despite low human population densities, the fishing communities along Baja California continue to provide the U.S. and Mexico with fresh WSB, which is predominantly transported in refrigerated vehicles across the international border (Ojeda-Ruiz et al., 2019).

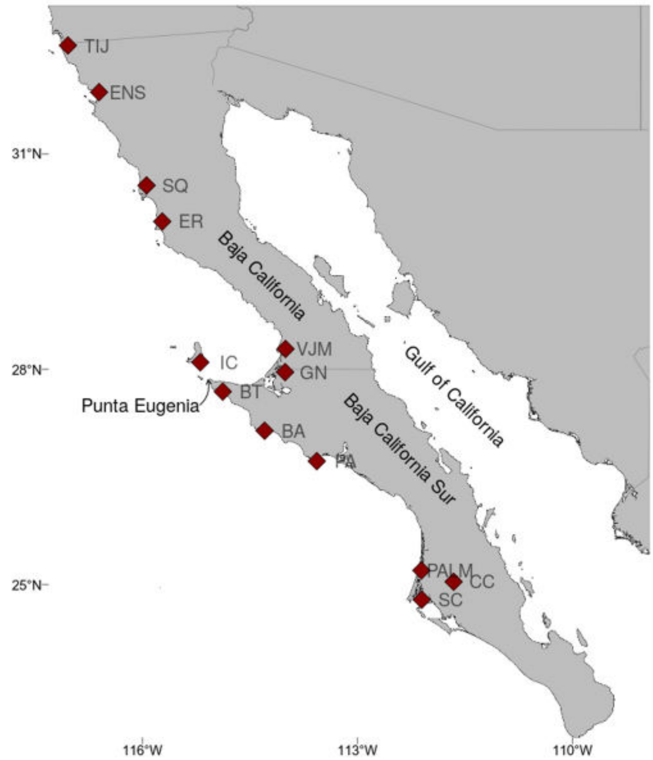

Fig. 1. The 13 local fisheries offices of the West Coast of the Baja California Peninsula referenced in the study. TIJ=Tijuana, ENS = Ensenada, SQ = San Quintín, ER = El Rosario, VJM = Villa Jesús María, IC = Isla de Cedros, GN = Guerrero Negro, BT = Bahía Tortugas, BA = Bahía Asunción, PA = Punta Abreojos, PALM = Puerto Adolfo López Mateos, CC = Ciudad Constitución and SC = San Carlos.

2.2. Reconstruction of the total white seabass Mexican landings: 1949–2019

To reconstruct WSB landings on the BCP west coast, we utilized a combination of reconstruction methods developed by Pauly (1998), Zeller and Pauly (2007), and Pauly and Zeller (2016a) for 273 regional fisheries around the world. Although the reconstruction approach described by Pauly and Zeller (2016b) typically consists of a seven-step process, we did not need to interpolate values between years (the typical step 5) because our time-series data did not have missing baseline catch records. Therefore, we utilized a modified six-step process to reconstruct WSB landings in the Mexican fishery:

2.2.1. Identification of existing baseline catch time series

As a baseline of catch time series, we used the Mexican official landings statistics compiled annually by several agencies of the Mexican Federal Government and published as the Fisheries Statistics Year Books (FSYB) from 1949 to 2018 (Arreguín-Sánchez and Arcos-Huitrón, 2007). At the time this manuscript was written, the 2019 FSYB had not been published. Since 2001, the agency in charge of the FSYB has been the Mexican National Commission of Fisheries and Aquaculture (CONAPESCA). Within the FSYB, WSB catch data have been pooled with landing records from eleven other regionally important sciaenid species into aggregate catch records reported under the category 'Corvina' (Escobar-Fernandez, 1989), creating the need to differentiate landings at the species level to reconstruct the time series for the BCP west coast. Disgregation of the 'Corvina' category to WSB species-specific is addressed in step 2.2.3.

2.2.2. Identification of fishing operations, locations, sectors, and periods with missing data

From the baseline data (FSYB), we reconstructed the 'Corvina' category landings in each of the two states (BC and BCS) and considered only landings on the BCP west coast from 1949 to 2019 (Table 1). In some years of the time series, the FSYB separated the 'Corvina' category geographically for the BCP west coast. However, in others, it was not reported geographically, so, based on proportions published in the grey literature, we separated the national landings of the 'Corvina' category firstly for the Pacific coast (including the Gulf of California), then for the states of BC and BCS, and finally for the BCP west coast. Meanwhile, from 2000 to 2019, and based on alternative data sources, landing data were segregated between two sectors of the Mexican fishery that harvested WSB along the BCP west coast: the small-scale fishery and the medium-scale fishery. We found that the medium-scale fishery started harvesting WSB across the BCP west coast in the early 2000s (Escobedo-Olvera, 2009). In contrast, only the small-scale fishery landed WSB prior to 2000.

2.2.3. Using alternative information sources to estimate missing data

To estimate the proportion of white seabass in the aggregated 'Corvina' records for the BCP west coast from 1949 to 2019, we carried out an extensive literature review (peer-reviewed and grey literature) and consultations with local fishermen and fishery experts. Proportions estimated for a region were used when no detailed information on WSB landing was found, which allowed us to reconstruct the quantity of WSB landed for several periods (Tables 1 and 2). Additionally, to estimate the proportions of WSB in the landings from 2000 to 2019, we used the Official Catch Landings Reports (OCLR) that CONAPESCA started to produce in 2001 and was made available through official channels upon direct request. The OCLR is an electronic database that contains compiled landing-slip records from small-scale and medium-scale fisheries and contains specific information such as, catch in dressed weight (i.e., eviscerated) by species or group of species, landing site, permit holder code, and name of the fishery office where the slips were submitted. The OCLR database allowed for the extraction of landings records by common fish name as reported at the 13 fishery offices along the west coast of the Baja California Peninsula from 2000 to 2019 (Fig. 1). After interviewing local fishermen and using the guide compiled by Ramírez-Rodríguez (2013), we extracted all catch records from the database that included common names associated with WSB. For the State of Baja California, all catch records with the common names of "Corvina Blanca" and "cabaicucho" records were selected. However, because the common name "cabaicucho" was used for a different serranid species (*Diplectrum pacificum*) within the state of Baja California Sur (BCS), records using this common name were not included into our landing estimates for BCS (Holguin-Quiñones, 1976; Pellowe and Leslie, 2017; Ramírez-Rodríguez, 2013). The OCLR time series were used to estimate the total WSB landings for the BCP west coast and estimate the proportion of WSB to be applied to the baseline time series of the FSYB.

2.2.4. Determination of anchor points for periods with limited catch data

When detailed catch records of WSB were found during our literature review, specific information was used to define anchor points at specific years to reconstruct landings data across periods with less precise details (see Table 1 for anchor points and Table 2 for references).

Table 1
Synthesis of the methodologies used in each reconstruction period. NA, Not applicable.

Period	Anchor period (white seabass species-specific landings)	Anchor periods mean proportion of white seabass	Corvina aggregate region data	Confidence interval (%)	Description reconstruction period	References
1949–1952	1949–1952	NA	Specific landings of white seabass	10	Almost all fishery resources landed on the west coast of the Baja California Peninsula were exported to the U. S. and, assuming that all the white seabass landed in Mexico were exported to the U.S., we considered that the records reported in 1949–1952 were the first species-specific landings for white seabass.	Berdegué (1956), Hool (1949), Hernández-Fujigaki (1988), Samaniego López (1999)
1953–1961	1949–1952	~4% Berdegue 1956	West coast of the Baja California Peninsula corvina aggregate	20	We estimated the mean proportion of white seabass for 1953–1961, and assuming similar fishing practices, we applied this proportion to the Corvina aggregate for 1953–1961	Secretaria de Industria y Comercio (1964)
1962–1973	1962–1973	NA	Specific landings of white seabass	20	Species-specific landings for white seabass were reported for the west coast of the Baja California Peninsula for 1962–1971.	McCall et al. 1976
1974–1976	1962–1973	~8% McCall et al. 1976	West coast of the Baja California Peninsula of corvina aggregate	50	Corvina group landings of the west coast Baja California Peninsula for 1974, 1975, and 1976. To estimate white seabass landings we used the mean ratio of ~8% from the last period	Secretaria de Industria y Comercio (1974); Departamento de Pesca 1979; INAPESCA, 1976
1977–1981	1962–1973	~8% McCall et al. 1976	West coast of the Baja California Peninsula of corvina aggregate	30	From 1977–1981, LFOs reported Corvinas group landings for the west coast of the Baja California Peninsula. Therefore, we estimated the landings for white seabass using the mean ratio of ~8%	Departamento de pesca 1979–1981
1982–1989	1962–1973	~8% McCall et al. 1976	BC and BCS of corvina aggregate	50	We estimated the proportion of corvina aggregate for the west coast of the Baja California Peninsula using the ratio of landings estimated for the corvina aggregate from the last period. And applied the mean ratio of ~8% to estimated landings for the white seabass	SEPESCA (1982-1994)
1990–1994	1990–1994	~97% Gobierno del Estado de Baja California (1995)	Specific landings of white seabass	30	On the west coast of Baja California, species-specific landings for white seabass were reported for 1990–1994, and a mean proportion was estimated for this period. Meanwhile, for Baja California Sur, determined Corvina aggregate was made for the west coast and estimated white seabass landings using the mean proportion estimated for Baja California.	Gobierno de Baja California., 1995 SEPESCA 1982–1994 SEMARNAP 1994–1999
1995–1999	1990–1994	~97% Gobierno del Estado de Baja California (1995)	BC and BCS of corvina aggregate	50	We estimated the mean ratio of white seabass landings from the Corvinas aggregate of 1990–1994 to determine the 1995–1999	SEMARNAP 1994–1999
2000–2019	2000–2019	NA	West coast of the Baja California Peninsula corvina aggregate	20	White seabass landings were estimated from Corvina aggregate landings reported by 13 Local Fishery Office of the west coast of Baja California Peninsula. Moreover, this period comprises information for the small-scale and the middle-size vessel fishery. Likewise, specific white seabass landings published in peer-reviewed journals were also incorporated.	SAGARPA, 2000–2017 SADER 2018 Ramirez-Rodriguez (2013) (Pellowe and Leslie, 2017; Cota-Nieto et al., 2018; Ojeda-Ruiz et al., 2018; Escobedo-Olvera, 2009)

2.2.5. Estimation of final total catch time series

Reconstruction of estimated landings for discrete-time periods was completed after time-series data derived from steps 2.2.2–2.2.4 were applied to the documented Corvina aggregate yearly landing records in the FSYB described in step 2.2.1 (Pauly and Zeller, 2016b). Depending on the year, the Corvina aggregated records were reported in the FSYB as nationwide, Pacific-wide, or for each Baja California or Baja California Sur state landing, making it necessary to estimate the proportions of WSB for the BCP west coast for each yearly total from 1949 to 2019.

Table 2
Main sources used for the historical reconstruction landings of white seabass in the West Coast of Baja California Peninsula.

Type of information	Period	Reference	Catch description
Mexican official landings statistics	1950–1956	SEMAR (1950–1969)	Corvina aggregate
	1952 and 1954	SEMAR (1950–1969)	Corvina aggregate by Fishery office BC and BCS
	1956–1961	Secretaria de Industria y Comercio (1964)	Corvina aggregate by Fishery office BC and BCS
	1962–1969	SEMAR (1950–1969)	Corvina aggregate
	1970–1974	Secretaria de Industria y Comercio (1974)	Corvina aggregate
	1975–1976	Departamento de Pesca (1975–1981)	Corvina aggregate
	1977–1980	Departamento de Pesca (1975–1981)	Corvina aggregate by Fishery office BC and BCS
	1981–1982	SEPESCA (1982-1994)	Corvina aggregate by Fishery office for BC and BCS
	1983–1993	SEPESCA (1982-1994)	Corvina aggregate for BC and BCS
	1994–1999	SEMARNAP (AEP 1994–1999)	Corvina aggregate for BC and BCS
	2000–2017	SAGARPA (2000–2017)	Corvinas aggregate for BC and BCS
	2018–2018	SADER (2018)	Corvinas aggregate for BC and BCS
	2000–2019	OCLR (200–2019)	Corvinas aggregate delimitated by common name and Fishery office BC and BCS
Quantitative descriptions of white seabass landings	1949–1952	Berdegué (1956)	Quantitative white seabass descriptions for West Coast of Baja California Peninsula
	1962–1973	MacCall et al. (1976)	Quantitative white seabass descriptions for the West Coast of Baja California Peninsula
	1990–1994	Gobierno del Estado de Baja California and Secretaría de Desarrollo Económico (1995)	Quantitative white seabass descriptions (specific landings in BC)
	2000–2006	Escobedo-Olvera (2009)	Quantitative white seabass descriptions for middle-sized vessels
	2000–2007	Cota-Nieto (2010)	Quantitative white seabass descriptions by Cooperativa Punta Abreojos
	2001–2015	Cota-Nieto et al. (2018)	Quantitative white seabass descriptions by Cooperativa Punta Abreojos
	2018	Ojeda-Ruiz et al. (2018)	Quantitative white seabass descriptions in Bahia Magdalena
Diverse literature	1949	Hool (1949)	Mexican fishery industry
	1968	Roedel and Frey (1968)	California based fisheries of the west coast of Mexico
	1976	Holguin-Quiñones (1976)	Catalogue of fishes from Baja California Sur
	1988	Hernández-Fujigaki (1988)	Mexican fishery history
	1994	Soberanes-Fernández (1994)	Historic description of the Mexican fishery
	1996	Ramirez-Rodriguez (1996)	% of total catches for the Pacific and the GC coast of BCS

(*continued on next page*)

Table 2 (*continued*).

Type of information	Period	Reference	Catch description
	1999	Samaniego López (1999)	Fisheries in Baja California
	2013	Ramírez-Rodríguez (2013)	Catalogue of fishes from the Mexican Pacific
	2015	Romo-Curiel et al. (2015)	Von Bertalanffy growth parameters for white seabass
	2016	Romo-Curiel et al. (2016)	Otolith isotope composition for white seabass
	2017	Pellowe and Leslie (2017)	Artisanal fishery species description BCS
	2020	García-Rodríguez and Sosa-Nishizaki (2020)	Artisanal fishing activities in Bahia Vizcaino Bay, B.C.S.

Table 3
Scores for the evaluation of the uncertainty associated with the Mexican white seabass landings reconstruction.

Score		Confidence interval +/-%	Corresponding IPCC criteria*	Historical species composition estimation criteria
4	Very high	10	High agreement & robust evidence	Quantitative white seabass descriptions
3	High	20	High agreement & medium evidence or medium agreement & robust evidence	Studies or surveys describing the white seabass fishery
2	Low	30	High agreement & limited evidence or medium agreement & medium evidence or low agreement & robust evidence	Studies only for one region along the west coast of the Baja California Peninsula
1	Very low	50	Low agreement & low evidence	Studies without a description of a specific region (i.e., National corvinas species group in Mexico)

Mastrandrea et al. (2011) noted that "confidence increases" (and hence confidence intervals are reduced) "when there are multiple, consistent independent lines of high-quality evidence".

2.2.6. Quantifying the uncertainty associated with each reconstructed period

The uncertainty associated with the historical reconstruction of the Mexican white seabass landings was evaluated using a scoring process developed by Zeller et al. (2015), which incorporated uncertainty criteria modified from the methodology used by the Intergovernmental Panel on Climate Change (Mastrandrea et al., 2011). We applied the results from a workshop with experienced scientists who individually reviewed the assumptions and scored the survey based on each time period and sector (Table 3). Survey scores were averaged for each period, and confidence intervals were obtained with the catch-weighted average (Table 3). The scoring periods evaluated were: 1949–1952, 1953–1961, 1962–1973, 1974–1976, 1977–1982, 1983–1989, 1990–1994, 1995–1999 and 2000–2019.

2.3. Fishery characterization

The FSYB and the OCLR do not report the fishing gears used to target WSB. Therefore, we carried out an extensive literature review (peer-reviewed and grey literature) and consultations with local fishermen and experts to describe the fishing gears used by the small-scale and medium-scale fisheries on the BCP west coast.

2.4. Analysis of the official catch landings reports 2000–2019

Between 2000 and 2019, OCLRs provided additional information that allowed us to establish yearly regional (BC and BCS) landing estimates by type of commercial fishery. Total catch was pooled across this period for each fishery office to estimate average (± SE) and maximum landing statistics for each region. Because assumptions of normality and homogeneity were not met, we performed non-parametric Kruskal–Wallis statistical analyses to test for differences by region (BC and BCS) and by type of commercial fishery (small scale and medium-scale).

Furthermore, OCLRs provided additional information related to the number of fishing days for the medium-scale fishery and the number of small-scale vessels participating in the commercial fishing for each region (CONAPESCA, 2015a,b). With this information, we estimated the catch per unit of effort (CPUE), where fishing days were used as a unit of effort for the medium-scale fishery, and the number of vessels was used as a unit of effort for the small-scale fishery. CPUE estimates for the medium-scale fishery were reported as average monthly catch per fishing days, while CPUE estimates for the small-scale fishery were reported as average monthly catch per number of vessels. Due to a lack of effort information from 2000 to 2005, CPUE analyses were only conducted for the 2006 and 2019 period.

3. Results

3.1. Fishery characterization

The WSB is a seasonal target species harvested along the BCP west coast, by a commercial gillnet fishery comprised of both medium-scale and small-scale vessels. The medium-scale fishery consists of boats between 10 to 27 m in length, equipped with hydraulic systems, inboard engines, and cold storage systems. Medium-scale fishery primarily harvest white seabass using either drift or set gillnets composed of 17 cm (6.5 in) nylon mesh, that are up to 2000 m in length. Following a national ban on drift-gillnet fishing for the medium-scale fishery in 2009, gillnets were primarily set along the bottom at depths between 1.8 to 18 m using anchors and a lead line along the base of the net and a floating line along the top. The average reported gillnet soak time was 9 h onboard medium-scale vessels targeting WSB.

Table 4
Mexican white seabass commercial fishery characteristics along the west coast of the Baja California Peninsula.

Fishery	Locality	Type of fishing	Description	Reference
Small scale	Pacific Coast of BC	Target and Incidental	Bottom gillnet with mesh size between 2–5 in.	Cartamil et al. (2011)
	Bahía Tortugas and Punta Abreojos, BCS	Target	Set gillnet and drift gillnet with lengths up to	Shester and Micheli (2011)
	Punta Abreojos, BCS	Target	Set gillnet with mesh size of 6.5 or 8 in and lengths from 100 to 500 m.	Cota-Nieto et al. (2018)
	Magdalena-Almejas Bay, BCS	Target	Set gillnet with mesh size of 6, 8 and 12 in. With length ranging 100 to 250 m	Ojeda-Ruiz et al. (2019)
	Bahía Sebastián Vizcaíno, BCS	Target and Incidental	Set gillnet, bottom gillnet, and seine net with mesh size of 5, 6, 8 and 10 in. With lengths between 200 to 6000 m. Some boats used hydraulic spools.	García-Rodríguez and Sosa-Nishizaki (2020)
	San Ignacio region, BCS	Target	Bottom and surfate nets.	Mendoza-Portillo et al. (2020)
	San Juanico, BCS	Target and Incidental	Set gillnet, bottom gillnet, and drift gillnet with a mesh size of 5.5 to 6 in and length of 100 to 200 m. Use of hydraulic spools in a single boat.	Interviews with local fishermen
Medium-scale	Esenada, BC	Target and Incidental	Until 2009, drift net gillnet with mesh size of 6.5 in and length of 2000 m. Incidental when targeting yellowtail (*Seriola lalandi*)	Escobedo-Olvera (2009)
	Bahia Magdalena Bay, BCS	Incidental	Incidental by the shrimp fishery	De la Rosa-Meza (2005)

Although WSB is a primary target of the gillnet fishery, they are also caught incidentally during gillnet sets targeting yellowtail (*Seriola lalandi*) and have also been reported as bycatch in the trawl fishery for shrimp (Table 4).

The small-scale fishery consists of boats between 7 to 10 m long, equipped with outboard engines and no cold storage systems. The WSB is a seasonal target species for small-scale fisheries, although it is caught year-round. The main fishing gear used to harvest WSB is the monofilament gillnet, with a mesh size ranging between 13 to 25 cm (5–10 in), set depths between 5 to 30 m, and lengths between 100 to 6000 m (when multiple gillnets are strung together). The average soak time for the gillnet is 24 h, but soak times can range between 4 to 48 h (Table 4). In the small-scale fishery, different gillnet configurations are tailored based on seasonal depth distribution and ocean conditions (i.e., set gillnet, bottom gillnet, drift gillnet, and seine gillnet; (Aalbers et al., 2021)). Outside of the spawning season (during winter months), bottom and set gillnets are most common, and the fishery switches to surface-based gear during the spawning season (late spring and summer months; May and June) when the WSB occur at shallower depths. When using the drift-gillnet configuration (typically deployed when WSB are in the upper water column), commonly referred to as "*garetear*", fishermen deploy gear late in the day and drift with the boat attached to the net all night. During the 12-hr soak time, the net is consistently checked and any WSB catch is immediately hauled to ensure better meat quality and to reduce predation by sea lions (Pers. Comm. Ignacio Romero, fisherman from San Juanico, BCS). During most small-scale fishery operations, fishermen hand-pull gillnets manually; however, hydraulic spools have been reported to be used recently, especially in the fishing camps of San Juanico, BCS, and Vizcaino Bay, BCS (Pers. Obs. AFY).

3.2. Regional fleet dynamics

Although the BCP has two well-established fleets that target WSB (i.e., small-scale, and medium scale), the small-scale operations in both BC and BCS make up the bulk of the overall effort.

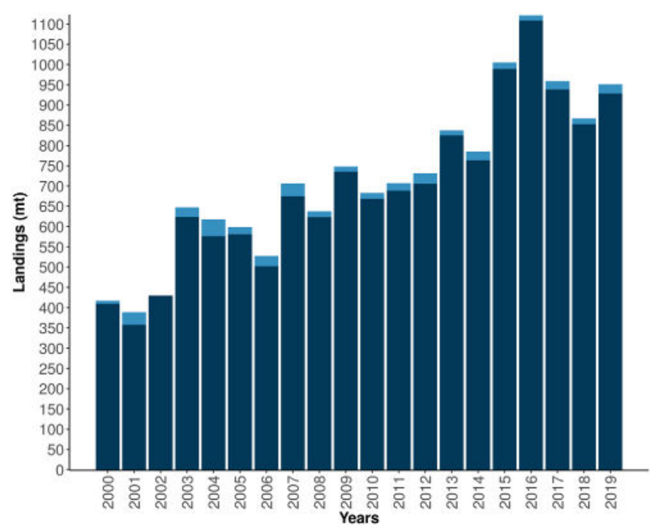

Fig. 2. Total annual landings of the Mexican white seabass fishery from 2000-to 2019 using the OCLR data. The dark blue color indicates the landings of the small-scale fishery, and the light blue color indicates the landings of the medium-scale fishery.. (For interpretation of the references to color in this figure legend, the reader is referred to the web version of this article.)

Based on the OCLR records, the small-scale fishery makes up ∼97% of the total WSB landings, while the medium-scale fishery comprised the remaining ∼3%. The landings of the small-scale fleet increased from 409 mt in 2000 to 928 mt in 2019, while the medium-scale fishery showed landings fluctuations between 7 to 40 mt (Fig. 2). Most of the landings for the medium-scale fishery fleet (mean 14 ± 8 mt y^{-1}) were recorded in BC, while BCS had the highest landings for the small-scale fleet (mean 599 ± 179 mt y^{-1}).

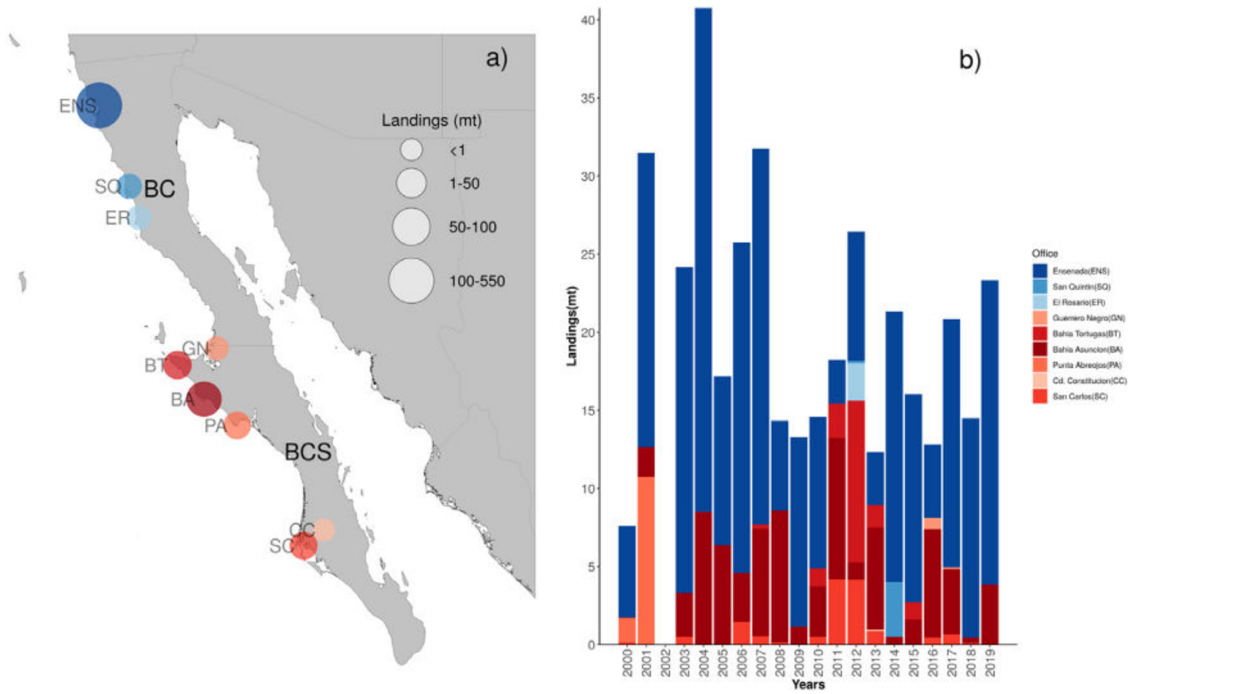

Fig. 3. 2000–2019 Fishery Offices landings for the medium-scale fishery. (a) Pooled landings for 2000–2019. (b) Landings by year for each Fishery Office. Only landings from 9 Fishery Offices are shown because the OCLRs only recorded those volumes for the medium-scale fishery.

The medium-scale fishery reported the highest pooled landings in the Ensenada fishery office with 261 mt and the lowest in the Ciudad Constitución fishery office with less than 1 mt (Fig. 3). Meanwhile, BC had the highest estimated nominal effort of 300 days (average monthly effort of 27 days) compared to the effort estimated for BCS with 200 days (average monthly effort of 16 days). However, there are no significant differences between effort estimates in both states (Fig. 4a), and the CPUE estimates for both states show similar trends (Fig. 4b). The months with the highest average landings for both states were June and July (Fig. 4c). Because the small-scale fishery makes up most of the WSB landings, the description of regional efforts is mainly focused on the efforts of the small-scale fishery.

3.3. Baja California (BC)

Within the state of BC, the Villa Jesus Maria fishery office reported the highest pooled landings from 2000 to 2019 for the small-scale fishery with 415 t (Fig. 5). Conversely, the lowest pooled landed volume for the same period was estimated for the Tijuana fishery office at approximately 1 mt (Fig. 5). The average nominal effort from 2006 to 2019 for the BC small-scale fishery was estimated at 1597 vessels and increased from 1122 vessels in 2006 to a maximum nominal effort of 2233 vessels in 2016 (Fig. 6a). The lowest CPUE estimated was 0.02 monthly catch (mt) per vessel in 2012 and the highest in 2007 with 0.09 monthly catch (mt) per vessel (Fig. 6b).

The highest average monthly WSB landings along BC occurred during the spring and summer seasons with a peak in June and July. Meanwhile, the lowest average monthly landings were recorded during the autumn and winter seasons, with the lowest average monthly landings in November (Fig. 6c).

3.4. Baja California Sur (BCS)

In BCS, the fishery office with the highest pooled landing volume from 2000 to 2019 was Ciudad Constitución with 4830 mt (Fig. 5). Because the fishery office of Puerto Adolfo López Mateos closed in 2006, there was a subsequent increase in landings slips recorded at the surrounding fishery offices from Ciudad Constitución and San Carlos (Erauskin-Extramiana et al., 2017). All fishery offices across BCS registered more than 500 mt of WSB captured by the small-scale fishery (2000–2019), with the lowest pooled landing estimate recorded in the Bahía Asunción fishery office(525 t).

A steady increase in the fishing nominal effort was reported from 2006 (1708 vessels) to 2019 (5222 vessels), with an average of 3773 vessels fishing during this period (Fig. 6a). The CPUE showed an increasing trend over time, with the highest estimated CPUE of 0.12 mean monthly catch(mt) per vessel in 2019 (Fig. 6b). The highest average monthly landings were recorded during the spring and summer seasons, with three notable peaks in June, July, and August (Fig. 7c). The lowest average monthly landings occurred during the transition between winter–spring and autumn–winter seasons, with the lowest landings in September (Fig. 6c).

3.5. Reconstruction of the total white seabass landings on the BCP west coast

In summary, the reconstruction efforts revealed only FSYB landings data for the period from 1949 to 2000, with both FSYB and OCLR data sources available for the later periods (2000–2019). Although similar trends were evident in both data sources, notable differences were identified between the two data sources. The reconstruction efforts revealed five distinct periods marked by the volume of landed product (Fig. 7). Based on FSYB records, initial landings fluctuated from 0.21 mt to 9 mt between 1949 and 1961. From 1962 to 1989, landing estimates fluctuated from 8 mt to 72 mt, showing a high increase up to 481 mt in 1990. During the 1991 to 2002 period, estimated landings fluctuated from 374 mt to 638 mt and from 2003 to 2014, landings estimates fluctuated between 467 mt to 966 mt. During the most

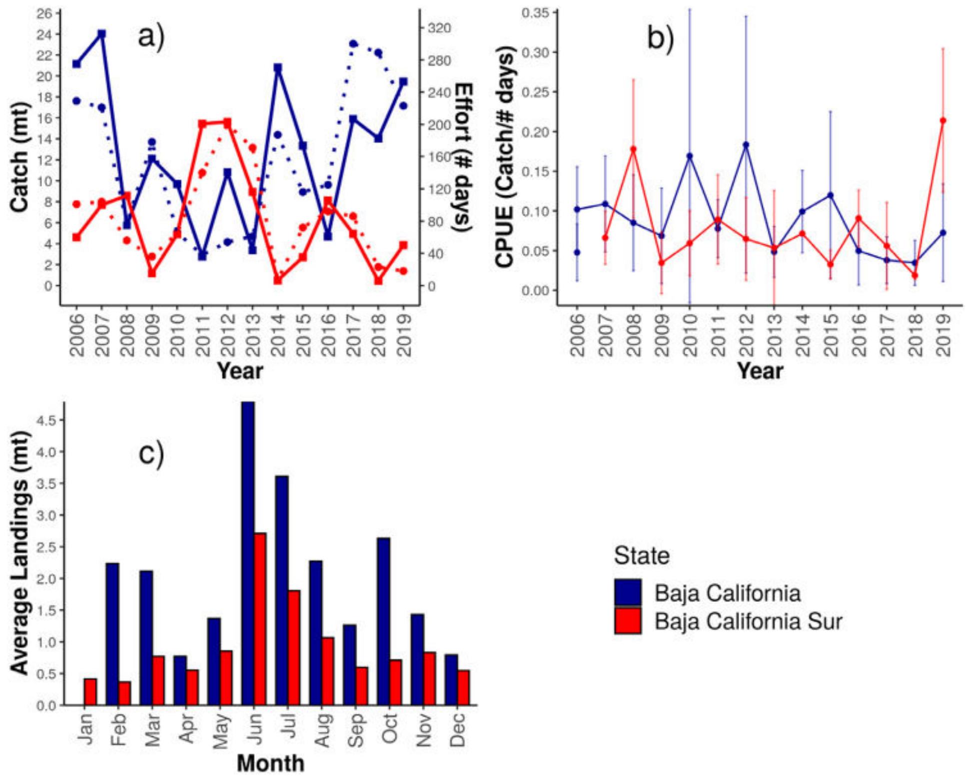

Fig. 4. Medium-scale fishery. (a) Nominal catch (mt) in solid lines and effort (#days) in dotted lines. (b) CPUE is estimated as the average monthly catch per day. (c) Average monthly landings.

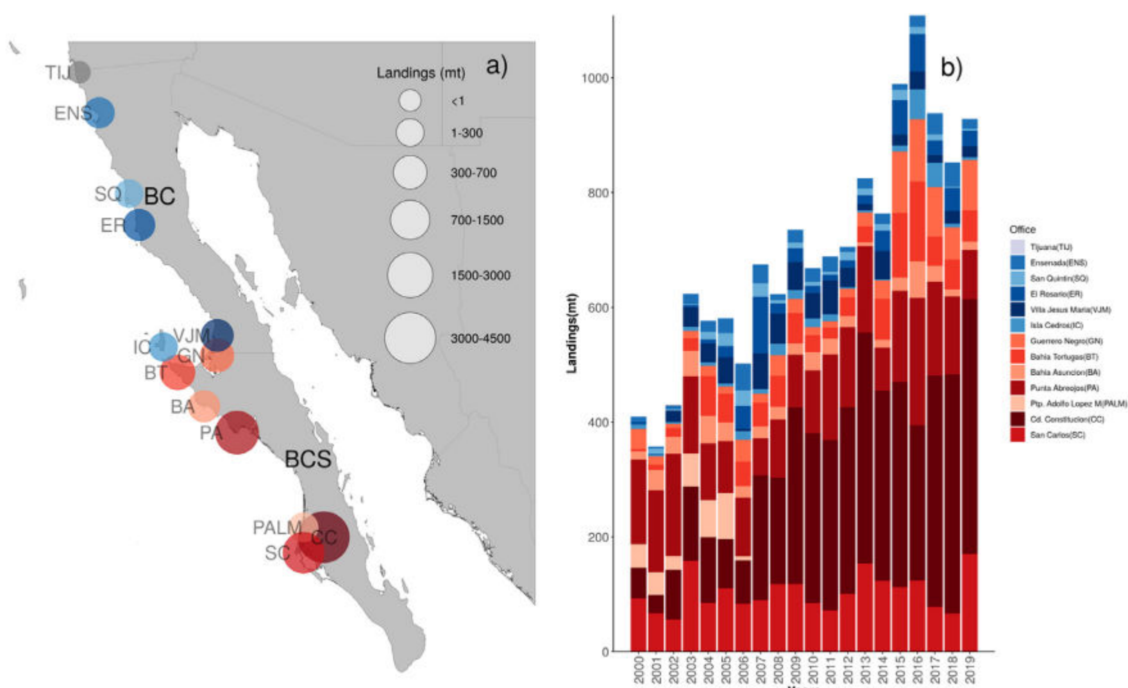

Fig. 5. 2000–2019 Fishery Offices landings for the small-scale fishery. (a) Pooled landings for 2000–2019. (b) Landings by year for each Fishery Office.

recent time period (2015–2018) reconstructed catch estimates from FSYB data sources increased to a peak of nearly 2000 mt in 2016 before declining to approximately 1402 mt in 2018 (Fig. 7). The OCLR records for this same overlapping period show landings to fluctuate between 300 mt and 1150 mt with an average of 718 mt from 2000 to 2019. The OCLR data show that annual landings increased from 417 mt yr^{-1} in 2000 to 952 mt yr^{-1} in 2019, revealing an overall increase of ∼228% (Fig. 7).

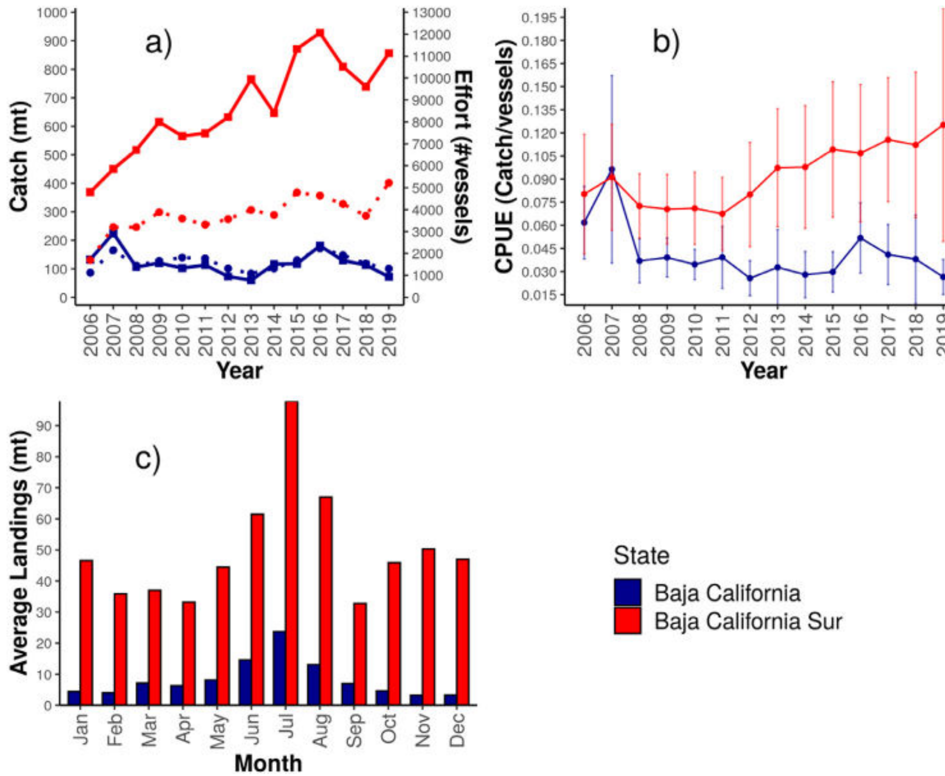

Fig. 6. Small-scale fishery. (a) Nominal catch (mt) in solid lines and effort (#vessels) in dotted lines. (b) CPUE is estimated as the average monthly catch per vessel. (c) Average monthly landings.

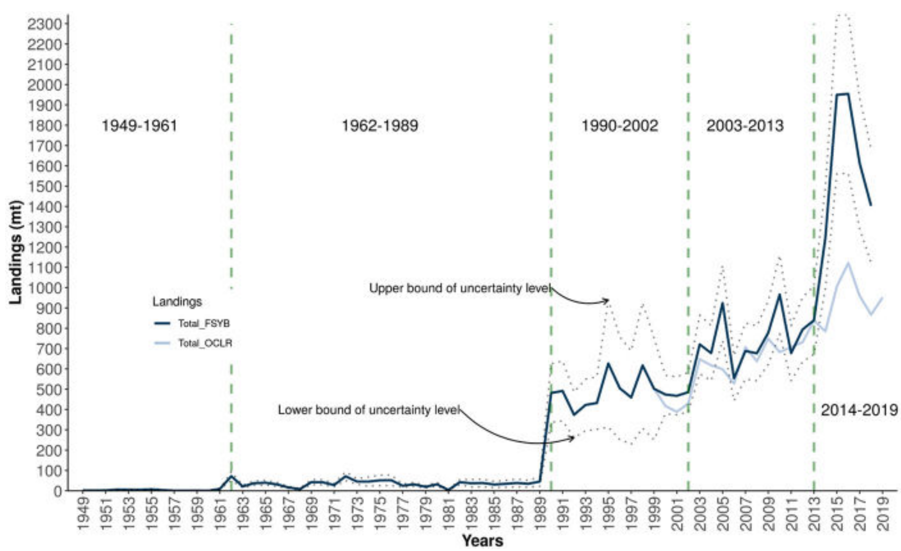

Fig. 7. Historical reconstruction of WSB Mexican fishery landings from 1949 to 2019. The dark blue line indicates total WSB landings from 1949-to 2019 using the FSYB as a baseline, and the light blue line indicates total WSB from 2000-to 2019 using the OCLR data.. (For interpretation of the references to color in this figure legend, the reader is referred to the web version of this article.)

3.6. Discrepancies and uncertainties associated with the landing's reconstruction

As shown in Fig. 7, this study found large discrepancies in the WSB landings estimates between the OCLR records (catch data obtained from fishermen landings receipts, see methods, Section 2.2) and the FSYB estimations (a combined croaker index compiled by resource managers for federal reporting purposes; see methods, Section 2.2). The estimated landings from the FSYB reached a peak of 2000 mt in 2016, while landing estimates based on OCLR records were much lower (∼1121 mt), resulting in a 74% discrepancy (Fig. 7; Table 5). For other years, differences between estimates based on FSYB and OCLR records fluctuated between −4.0% and 94% (Table 5). The rationale behind the apparent discrepancies is provided in Section 4.2.1.

The mean weighted percentage uncertainty of the reconstructed WSB landings based on FSYB is shown in Fig. 7. The uncertainty estimated for the reconstructed landings of WSB has narrower confidence intervals for the periods 1949–1952 (10%),

Table 5
Reconstructed landings from OCLR and FSYB their differences (Diff) and Diff%. Also, the size of the US WSB market in metric tons, California (CA) landings, Mexican estimated imports to cover the 75% of the US market (Mex75), mean USD/Kg WSB value, and US total market value (CDFG, 2020a).

Year	OCLR	FSYB	Diff	Diff %	CA_mt	Mex75_mt	US Market_mt	US Market USD/kg	US Market USD$ Value
2000	417	474	57	13.6	99	296	395	4.4	1,746,508.36
2001	389	467	79	20.2	118	355	473	4.1	1,933,904.24
2002	430	486	56	13.0	189	567	756	4.0	3,029,484.17
2003	648	721	73	11.3	203	608	811	3.8	3,084,995.13
2004	617	678	60	9.8	135	404	539	4.5	2,426,690.55
2005	598	924	326	54.4	133	399	532	5.7	3,040,838.03
2006	528	554	26	5.0	174	522	697	4.6	3,186,922.60
2007	707	688	−18	−2.6	209	627	836	5.5	4,619,881.87
2008	637	677	39	6.2	293	880	1174	5.1	6,025,850.78
2009	749	778	29	3.9	176	528	705	4.9	3,457,900.59
2010	683	966	283	41.5	249	746	995	6.2	6,194,729.75
2011	707	678	−29	−4.1	248	743	990	6.6	6,538,622.33
2012	732	794	62	8.5	176	528	705	7.9	5,602,309.47
2013	837	840	2	0.3	114	343	458	8.8	4,028,875.05
2014	785	1247	462	58.8	119	358	477	9.5	4,533,133.76
2015	1005	1949	944	93.9	93	280	373	9.6	3,595,545.77
2016	1121	1954	833	74.3	105	316	421	8.1	3,408,669.55
2017	959	1612	652	68.0	104	311	415	8.9	3,696,655.08
2018	867	1403	536	61.8	108	325	434	9.2	3,980,104.11
2019	952	NA	NA	NA	70	209	279	10.5	2,935,597.69

*NA = Not applicable.

followed by a 20% uncertainty estimate for the periods of 1953–1961, 1962–1973, and 2000–2019. Meanwhile, the periods with the broadest confidence intervals were 1977–1982, 1990–1994 with 30% and 1974–1976, 1983–1989, and 1995–1999 with 50%.

4. Discussion

4.1. Summary of reconstruction efforts along the BCP west coast

The main objectives of this work were to collate and reconstruct Mexican WSB landings from the start of the commercial fishery, which we estimate originated in 1949. When coupled with the documented harvest from California-based vessels (1916–1982), it is evident that the white seabass stocks along the Pacific coast of North America have now been exploited for over a century (Coleman, 1923; Radcliffe, 1922; Skogsberg, 1939, 1925). Although the reconstructed landings records show an overall increase in WSB landings over the past 70 years (Fig. 7), this work highlights the complexity of this fishery and reveals regional differences that are likely related to regional abundance and population dynamics (Valero and Waterhouse, 2016). This study has also identified fluctuations in WSB landings that are likely in response to other factors such as international market dynamics, environmental conditions, and the political context of the period (Caddy and Gulland, 1983; Mcclenachan et al., 2012a).

Because it is often difficult to quantify how environmental changes impact landings or fishery dynamics, this study focused primarily on describing trends relative to contextual factors and geopolitical events (i.e., fishery management policies, market development, transportation) (Espinoza-Tenorio et al., 2011; Cisneros-Montemayor et al., 2013; Saldaña-Ruiz et al., 2017; Sosa-Nishizaki et al., 2020). Landings data were summarized and compared over a geopolitical timeline that considered administration priorities at the time, regional changes in infrastructure, and any events that may have influenced effort or trade. Based on these historical accounts this work was able to divide the history of the landings into five development periods that range from the beginning of the commercial fishery in 1949 to the present day. In the following sections, we described the five periods.

4.1.1. (1949–1961) Beginning of the western coast of Baja California Peninsula local fishery

Fishing along Baja California was initiated through pressures from the Mexican government to develop a regional fishing industry in the 1920s, that included small catches of WSB. This was coupled with support from Japanese and American investors that reinforced fishery development efforts focused on high-value species (i.e., abalone, lobster, and tuna) (Chenaut, 1985; Crespo Guerrero and Pelcastre, 2017; Velázquez Morales, 2007). In the 1930s the BCP began to see the development of its first fishing cooperatives, community fishing groups that were established to increase and expand local fish production (Aguilar-Ibarra et al., 2000; McCay et al., 2014; Samaniego López, 1999). Following management policies of the 1940s that promoted expansion and growth, the Baja California fishing industry became one of the largest national fisheries of the time (Berdegué, 1956; Hool, 1949). During this period the Mexican government fostered technological developments, industrial fisheries regulations, and the renovation of communication ports, electrical networks, and roads to strengthen the international market trade between Mexico and the U.S. (Espinoza-Tenorio et al., 2011; Hool, 1949). It was during this era (1949) that the exportation of WSB from Mexico to the U.S. was first documented (Berdegué, 1956). Although we can assume that WSB harvest predated this era, this was the first period for which there were any records or landings data for this species in Mexico. During this initial period (1949 and 1961), WSB landings fluctuated from 0.21 mt to 9 mt (Fig. 7).

4.1.2. (1962–1989) Growth of the Baja California WSB fishery

During this period the BCP saw several large changes that directly affected the WSB fishery. For one, in 1976 the Mexican government established its Exclusive Economic Zone (EEZ), which led to the official closure of its waters to foreign fishermen in 1982 (Cicin-Sain et al., 1986). This change prohibited U.S. fishermen from seasonally fishing for WSB in Mexican waters and led to a rapid decline in WSB landings off California (Cicin-Sain et al., 1986; Vojkovich and Reed, 1983). During this period, WSB landings fluctuated from 8 mt to 72 mt (Fig. 2), with products consumed locally and also exported to U.S. markets (MacCall et al., 1976). In addition to the establishment of a national EEZ, the Mexican government also enacted new federal laws to help develop and promote local fisheries (Aguilar-Ibarra et al., 2000;

Cicin-Sain et al., 1986; Soberanes-Fernández, 1994). This era also saw the establishment of parastatal agencies, the promotion of fishery loans as well as increased marketing and processing of marine fishery resources (BANPESCA, 1980; PROPEMEX, 1972 and Ocean Garden 1975; Espinoza-Tenorio et al., 2011; OECD, 2006). Additionally, the completion of the Transpeninsular Federal Highway in 1973 increased market connectivity and trading between the U.S. and Mexico (Crespo Guerrero and Pelcastre, 2017). Collectively, fishery development efforts and changes to local infrastructure resulted in nearly twice the total WSB landings by Mexican fishermen during this period compared with the previous fishing period (Fig. 7).

As with other eras, Mexico also reported periods of fluctuating WSB harvest affected by different factors including a period in the early 1980s when the international oil market led to a country-wide economic crisis that impacted parastatal agencies and resulted in a fall in the local fisheries production (Aguilar-Ibarra et al., 2000; Espinoza-Tenorio et al., 2011; Martinez de la Torre, 1994). These historical factors likely explain the abrupt fall of WSB production to 3.49 t in 1981 (Fig. 2). Similarly, other marine resources that domestic fishing cooperatives had exploited (i.e., abalone, sea turtle) similarly showed similar decreases in landings during this period. It was also during this period that local fishing cooperatives, which formerly focused primarily on lobster, began to diversify, and harvest finfish to offset declines in production. Species like WSB were targeted, mainly because their large size provided high-quality fillets that were readily marketable (Cota-Nieto et al., 2015; Early-Capistrán et al., 2018; Prince and Guzmán del Próo, 1993). Despite periods of reduced harvest, fishery landings increased dramatically from a low of 3.49 mt in 1981 to 45.32 mt in 1989 (Fig. 7).

4.1.3. (1990–2002) Establishment of the Mexican WSB fishery

This period started with a large increase in WSB landings which went from 45 mt in 1989 to 480 t in 1990 and later fluctuated between 374 mt to 486 mt, suggesting that the local WSB fishery had reached a period of stabilization along the western coast of the Baja California Peninsula. Two main factors that contributed to the increase observed during this period were improvements in fishing gear, such as the widespread use of fiberglass boats and monofilament gillnets (Álvarez et al., 2018), along with an increase in the number of small-scale vessels participating in the directed fishery (Martinez de la Torre, 1998; OECD, 2006; Young, 2001). Increased participation in the directed WSB fishery may have also been influenced by the total ban of traditional sea turtle fisheries in 1990, which forced fishermen to target other resources (DOF, 1990; Early-Capistrán et al., 2018). The development of a new Federal Law that established a system of permits and removed exclusive fishing rights from the cooperatives also allowed fishers to participate in different fisheries more readily (McCay et al., 2014; OECD, 2006). A strong export market for WSB was developed in California and trade between Mexico and the U. S. was further complemented with the establishment of the North American Free Trade Agreement in 1994 (Young, 2001).

4.1.4. (2003–2013) Rise of the Mexican white seabass fishery

This period was characterized by an increasing trend in Mexican WSB landings that fluctuated between 600 to 900 mt and peaked in 2010 at 966 mt (Data from OCLR Fig. 2). Heightened landings during this period (Fig. 7) suggest that the WSB role in local fisheries was further solidified along the entire BCP (Cartamil et al., 2011; Rosales-Casián and Gonzalez-Camacho, 2003), with increased targeting by Fishing Cooperatives of the North Pacific (Shester and Micheli, 2011), both within the Ulloa gulf (Cota-Nieto et al., 2018) and Magdalena-Almejas Bay (Ojeda-Ruiz et al., 2019, 2018). During this period the WSB had also become an important fishery resource of the medium-scale fishery fleet which mainly fished out of Ensenada (BC) and the Port of San Carlos (BCS). The Mexican government banned the use of drift gillnet gear for sharks and swordfish in 2009 (DOF, 2007; Escobedo-Olvera, 2009), which may have been responsible for the decline in landings observed at the end of the period (Fig. 7).

4.1.5. (2014–2019) Boosting fish consumption and international markets

This period is characterized by a large increase in WSB landings and stark differences between the two sources of information used to reconstruct WSB catch along with the BCP. Data obtained from the FSYB showed that WSB landings increased from 1250 mt in 2014 to a peak of ~2000 mt in 2016, before declining to 1402 mt in 2018 (Fig. 7). In contrast, WSB landings estimates obtained from the OCLR show that for the same period catch estimates were between 59%–94% lower than FSYB statistics. Based on the OCLR data, it was estimated that WSB landings increased from 785 mt in 2014 to a peak of 1121 mt in 2016, before declining to 867 mt in 2018 (Fig. 2). Although both estimates show a large increase in WSB landings, annual discrepancies were substantial and possibly attributable to the inclusion of other croaker species in the WSB estimate, or possibly reporting errors in the FSYB database (Table 5, see the following Section 4.2.1 for discussion on catch estimation discrepancies).

Moreover, the period from 2014 to 2019 coincides with an administrative term during which the Fishery and Food Development Program of Mexico was actively promoting the consumption of fishery and aquaculture products (DOF, 2013). To enhance fishery operations, subsidies for both small and larger-scale fisheries were offered to promote harvest and regional production (Cisneros-Montemayor et al., 2016). Given the basis for federal subsidies, there may have been an incentive to report higher levels of the catch than what was actually harvested (Cisneros-Montemayor et al., 2016). The economic incentives during this period allowed small-scale fishermen to enhance the efficiency of their operations by purchasing better equipment and upgrading platforms to increase effectiveness (i.e., larger gillnets, newer motors). Consistent demand and increased exports to U.S. markets also helped support increased landings during this period. Moreover, it is estimated that Mexico (principally the BCP) continues to supply 75% of the U.S. WSB market volume, with an estimated 400 t imported annually at a mean value of $3.7 million dollars (data from 2014 to 2019; Table 5; CDFG, 2020b).

4.2. Discrepancies and uncertainties associated with the landing's reconstruction

4.2.1. Discrepancies associated with the landing's reconstruction

Although it is difficult to identify the exact cause for discrepancies between data sources, similar inconsistencies have been described for other fisheries around the world (i.e., Chinese marine fisheries catch) based on changes in administrative reporting policies (Watson and Pauly, 2001). Additionally, it may be possible that FSYB statistics represent aggregate landings comprised of both WSB and other croakers (corvinas) that were marketed under the same label in response to the growing market demand for WSB during this period.

Because the OCLRs are comprised of the "raw" catch data obtained directly from landings slips, we consider the OCLR estimates to be more reliable than the FSYBs. Moreover, the OCLRs have recently been used to characterize other local fisheries in Mexico, such as the finfish fishery (Ojeda-Ruiz et al., 2018) and the serranid fisheries in Magdalena-Almejas Bay, BCS (Erauskin-Extramiana et al., 2017). In contrast, FSYB estimates are calculated based on other variables that may influence data quality such as the transfer of fishery information between management levels (i.e., from fishermen-to fishery offices, from fishery offices to state offices, and from state offices to central offices) (Arreguín-Sánchez and Arcos-Huitrón, 2007).

4.2.2. Uncertainty associated with each reconstructed period

The periods with the highest associated uncertainty (i.e., larger confidence intervals) primarily occurred when fishery office data were absent and only Corvina aggregate data were available. Meanwhile, the periods with reduced uncertainty (i.e., tighter confidence intervals) were mainly related to the presence of specific landing reports for WSB, detailed descriptions of WSB harvest in peer-reviewed, grey, and historical literature, and the existence of fishery office data (Berdegué, 1956; Cota-Nieto et al., 2018; Escobedo-Olvera, 2009; MacCall et al., 1976). The rationale supporting reduced uncertainty in the early years of the reconstruction is based on studies by Berdegué (1956) which detailed species-specific catch information for the northwest coast of Mexico. This level of species-specific detail contrasts with subsequent years which reported on general aggregate landings data, which often lacked species-level information (FSYB).

Although this study used the best available information to reconstruct the historic landings of the WSB in Mexico, the methodology we used has been shown to be associated with the inconsistency and uncertainty of non-standardized data sources (Zeller et al., 2015). We evaluated the uncertainty of our reconstruction based on a scoring process to evaluate the quality of our time-series data and the methods used in each period (Zeller et al., 2016). Although Cisneros-Montemayor et al. (2013) highlighted a decrease in unreported Mexico landings, we did not standardize our data because a non-reporting ratio was unavailable for each period. Additionally, even though some studies have highlighted the importance of WSB in the recreational fisheries of Mexico (García-Rodríguez et al., 2013; Rodrigues-Medrano, 1993), landings data are not available for this sector of the fishery.

4.3. Official catch landings data 2000–2019

The reconstruction efforts have identified the OCLR database to be the most accurate and useful for understanding regional trends in both effort as well as the volume of WSB landed. Although not perfect, these data do provide managers with baseline information that can be used to gauge economic importance and assess changes in relative volume landed by region and season. Our results are consistent with previous studies that also discuss the importance of the WSB as a fishery resource for local communities in BC and BCS (Romo-Curiel et al., 2015, 2016; Rosales-Casián and Gonzalez-Camacho, 2003). From similar analyses of OCLR data, Ojeda-Ruiz et al. (2019) documented the continued reliance upon the WSB by fishers of the Magdalena-Almejas Bay region, and its importance in mitigating the social impacts of recent fishery closures to the Catarina clam (*Argopecten ventricosus*) fishery in 2012. They considered barred sand bass (*Paralabrax nebulifer*), ocean whitefish (*Caulolatilus princeps*), and WSB as the main species in the finfish fisheries along the BCP. Cota-Nieto et al. (2018) also reported the WSB to be a resource of great importance to the Punta Abreojos Fishing Cooperative, as it represents the fourth highest revenue source, just below the spiny lobster (*Panulirus interruptus*), abalone (*Haliotis spp.*), and verdillo (*P. nebulifer*).

With the information estimated in this study and the lack of any formal stock assessment, it is not possible to determine the current status of the WSB fishery in Mexico. Continuous monitoring of landings and additional fishery information (e.g., comprehensive effort information, length–frequency data) are needed to better understand predictors of stock status.

4.3.1. Regional trends

From a total harvest perspective, it is notable that the Mexican fishery has shown a steady increase in landings over the past 20 years, reaching its peak in 2016 (Fig. 7). The majority of WSB harvest has come from BCS (∼84% mean from 2000 to 2019), with landings concentrated primarily in the regions of Ciudad Constitución, Punta Abreojos and San Carlos (OCLR data, Fig. 5). Meanwhile, fisheries from BC more closely resemble those off California, with a peak in 2007 and relatively suppressed landings and effort since 2008 (Fig. 6a). California WSB landings have also been shown to be in decline since 2008 with spawning stock biomass estimated at just 24% of the historical level (Valero and Waterhouse, 2016). Although the lack of information for Mexican fisheries precludes our understanding of the current regional status, several factors may contribute to the differences observed in landings volume and effort trends between BC and BCS. It is possible that the fisheries across BC and BCS target different WSB stocks that vary in terms of their current population status. Based on historic landings data from CA gillnet vessels fishing along the BCP prior to the closure of Mexican waters to U.S. vessels in 1982, fishers would travel to the waters of BCS to capitalize on the abundant WSB resource during periods of reduced WSB availability along CA (Vojkovich and Reed, 1983; Valero and Waterhouse, 2016). It has been suggested through tagging, genetics, and age-growth studies that more than one putative stock may exist along the BCP (Romo-Curiel et al., 2015; Franklin et al., 2016; Aalbers et al., 2021). Based on electronic tagging data, it has been proposed that California WSB seasonally extend into northern Baja with limited movements below Punta Eugenia (the border between BC and BCS).

It must also be considered that BCS has a larger fishing community than BC (60 fishing communities vs. 44; Ramirez-Amaro et al., 2013), which could also partially explain the higher estimated effort (greater number of vessels) and landings within the BCS region (Fig. 6a). Estimates in the level of effort and CPUE may also be functionally different between regions given the use of hydraulic-powered net spools by some of the small-scale vessels within the larger BCS fishing communities (San Juanico and Vizcaíno Bay; Table 4). Moreover, the highest BCS landings were concentrated in traditionally productive fishing grounds (such as Magdalena-Almejas Bay, Ulloa gulf, and Vizcaíno Bay), which have also been associated with higher landings of the giant sea bass (*Stereolepis gigas*; Ramírez-Valdez et al., 2021). Productive inshore areas of Vizcaíno Bay and San Juanico Bay, BCS were also identified to have the highest concentrations of WSB larvae during the months of May–August (Moser et al., 1983). Nonetheless, further investigation of the differences between the two regions is needed to better understand the fishery dynamics and management needs of the Mexican WSB fishery.

4.3.2. Seasonal trends

Our study estimated that the highest seasonal landings occurred in the summer months of June and July, matching the spawning season described for WSB (Aalbers, 2008; Aalbers and Sepulveda, 2012). Similar seasonal patterns have also been reported for WSB along CA, suggesting that the resource is most vulnerable to exploitation during the spawning season across its entire range. Given that the seasonality of peak harvest is similar in CA, BC and BCS, it may be that regional fisheries rely upon different segments of the spawning stock rather than the same population being harvested across all three regions. Elevated landings is commonly observed for various serranid species in Magdalena-Almejas Bay, BCS, during the spawning season (Erauskin-Extramiana et al., 2017) and groupers in the Gulf of California (Erisman et al., 2007). Although fish spawning aggregations have been identified as highly vulnerable to overfishing, certain species may be harvested sustainably when managed properly (Erisman et al., 2014).

Unlike CA, which has implemented a seasonal closure on commercial WSB fishing, Mexican fisheries still fish this species year-round, peaking during the spring and summer months. Similar to the CA fishery, commercial operations along the BCP target WSB at different depths depending on the season, using gillnets either suspended from the surface or set along the bottom. Electronic tag data has shown that WSB occurred shallower during the spring and summer spawning season and at deeper depths between October and March (Aalbers et al., 2021). Commercial fishers along BC and BCS seasonally adapt their gear to either drift near the surface at night or to target fish along the ocean floor using demersal gillnets (Cartamil et al., 2011; García-Rodríguez and Sosa-Nishizaki, 2020). Unlike CA, which has implemented a seasonal ban on WSB, Mexican fisheries can target this species year-round. However, the WSB could be favored in its protection along the west coast of the BCP during the winter and spring months from an umbrella effect due to more valuable fishery resources being harvested in this season, such as the lobster and abalone, decreasing the fishing effort for finfish resources (Briones-Fourzán and Lozano-Álvarez, 2000; Cota-Nieto et al., 2018).

Nonetheless, given recent increases in effort and advancements in gear along BCS (i.e., hydraulics and larger nets), additional resources and monitoring efforts may be needed to estimate the stock status and prevent the decline in WSB landings previously been observed off CA. Because the small-scale fishery registers the highest landings of WSB, it is necessary to enhance the importance of the communities associated with this fishery in managing the species (McCay et al., 2014). Several studies have demonstrated that co-management and participatory management of those communities are key components to achieving economic and ecological sustainability (Gutiérrez et al., 2011; Finkbeiner and Basurto, 2015).

4.3.3. Trends in CPUE

The CPUE estimates generated in this study offer insight into the fishery dynamics of the region, but should also be viewed with caution, as several relevant factors (i.e., fleet efficiency and environmental factors) were not accounted for (Maunder and Punt, 2004). Moreover, the landing slips that constituted the primary tool for developing OCLRs were compiled on a weekly or monthly basis and did not reflect daily effort or catch. Other limitations and inconsistencies, such as the aggregation of taxa under a single common name (i.e., corvina complex) and missing information in required data fields often presented constraints to generating accurate CPUE estimates. Discrepancies in vessel operations and fishing gear, such as the number and size of the nets deployed, the size of the gillnet mesh and whether the gillnet was hand-pulled or mechanized may have also influenced CPUE estimates.

In a previous study, Cota-Nieto et al. (2018) proposed a decreasing trend in the CPUE for the white seabass for the Punta Abreojos Fishing Cooperative between 2001–2007 contrasted by an increasing trend from 2007 to 2013. Although Cota-Nieto et al. (2018) also reported a large decline in effort (less than 500 trips) for WSB in 2007, this period was also characterized by increased effort and landings of lobster and abalone, two species with higher market value than the WSB. The effort shift reported by Cota-Nieto et al. (2018) is likely responsible for some of the changes in effort and landings reported for WSB in different areas along the BCP. From interviews and through the efforts data, it has become evident that most WSB fishers are portfolio fishermen that often change target depending upon availability and market price. Cota-Nieto et al. (2018) reported similar harvest trends during this period for other fin-fish resources [i.e., yellowtail (*Seriola lalandi*), whitefish (*Caulolatilus princeps*), California halibut (*Paralichthys californicus*) and speckled flounder (*Paralichthys woolmani*)]. Thus, the CPUE fluctuations observed in this study likely include regional variation and should be viewed from a general perspective rather than a year-to-year basis.

More detailed information is needed to address the lack of information in the OCLR and estimate a more reliable CPUE to be used in a stock assessment. The reliability of fishery-dependent CPUE estimates depends on the descriptions of fishing gear (i.e., mesh size of nets, length of nets), fishing power (i.e., size of boats, type of net retrieval, whether manual or mechanical), and effective fishing effort (i.e., soak times) associated with catches. A fraction of the catches related to accurate fishing effort helps estimate relative abundance indices that can be compared between regions, boats, and cooperatives. More accurate information on fishing efforts may result from conducting fishery-independent data collections or more thorough examinations of select logbooks obtained from Fishing Cooperatives. For example, the study conducted by Cota-Nieto et al. (2018) used information from the Punta Abreojos Fishing Cooperative to estimate a WSB CPUE based on the catch and the number of boat trips. In addition to more reliable CPUE estimates, information related to the length composition of the catches, coupled with additional biological information (i.e., size at maturity), may allow for a better determination of appropriate size limits and fishing gear restrictions. Future work aimed at filling critical data gaps may allow for improved species-specific management strategies as well as co-management efforts with the U.S.

4.4. Management implications

Several studies have discussed the importance of bi-national management for ensuring the sustainability of transboundary resources (Sumaila et al., 2020; Palacios-Abrantes et al., 2020; Ramírez-Valdez et al., 2021). However, it is important to reduce data inconsistencies across borders to better achieve this goal. For example, recently, Ramírez-Valdez et al. (2021) highlighted the asymmetry in management and research information between the U.S and Mexico for the giant seabass (*Stereolepis gigas*) that resulted in a biased view of the population status. Moreover, it emphasized the importance of a continually developing process of new information to comprehend transboundary marine resource connectivity, distribution, and stock structure for effective management in both countries.

Indices of relative abundance, such as CPUE, size, and age composition data, coupled with life-history parameters, could be helpful to define spatial distributions and delineate stock boundaries (Begg, 2005; McBride, 2014). Furthermore, specific information from fishery reporting areas could be used indirectly to better define putative stocks (Cadrin, 2020; Halliday and Pinhorn, 1990), or at least reveal the spatial structure of the population based on fishery dynamics. For example, three stocks of silver kob, *Argyrosomus inodorus*, were identified by regional differences in catch records, life history parameters, and CPUE estimates along the South African coastline (Griffiths, 1997). Likewise, Ames (2004) used an interdisciplinary approach to define the stock structure of Atlantic cod by combining fishing records and fishermen interviews. Although variations in fishing effort could mask landings volumes, there is a significant difference between landings volumes of BC and BCS from 2000 to 2019. Differences in the volume of WSB landings between the northern and the southern regions, along with differences in life-history traits (Romo-Curiel et al., 2015), environmental conditions (Romo-Curiel et al., 2016), genetic analysis (Franklin et al., 2016), and tagging data (Aalbers et al., 2021), all suggest limited movements between BC and BCS.

Also, several studies indicate the importance of bi-national management for transboundary resources to maximize fishery sustainability (Sumaila et al., 2020; Palacios-Abrantes et al., 2020; Ramírez-Valdez et al., 2021). However, it is important to reduce data inconsistencies across borders to achieve this goal better, especially if it is necessary to assess the stock by pooling the data. For example, Ramírez-Valdez et al. (2021) highlighted the asymmetry in management and the research information between the U.S and Mexico for the giant seabass (*Stereolepis gigas*) that resulted in a biased view of the population status. Moreover, it emphasized the importance of a continually developing process of new information to comprehend transboundary marine resource connectivity, distribution, and stock structure for effective management in both countries.

5. Conclusions

This study integrated the best available information to reconstruct the landings of a historic transboundary fishery resource in a data-poor context. Fluctuations in WSB annual landings were associated with shifts in contextual factors, such as fisheries management policies and market changes during five specific periods over the past 70 years. Moreover, the small-scale fishery along the west coast of the BCP reported the highest landings of WSB over the past 20 years, firmly establishing its regional importance of this fishery. Contrasting regional trends in fishery landing rates and effort between BC and BCS combined with evidence from life-history, genetic and tagging studies, all provide evidence of two putative stocks of WSB within its Pacific distribution. Nonetheless, further investigations between the two regions is needed to better understand the fishery dynamics and management needs of the Mexican WSB fishery. As previous studies have proposed, this work supports the need for the continued collection of new and accurate information to better understand the connectivity, distribution, and stock structure of this transboundary resource. Furthermore, due to the importance of WSB as a fishery resource for the small fishing communities of the west coast of the BCP and the lack of directed management efforts, the landings reconstruction and CPUE trends offer a baseline to establish co-management efforts between stakeholders and local communities to improve the sustainable use of this resource.

CRediT authorship contribution statement

A. Fajardo-Yamamoto: Conceptualization, Investigation, Data curation, Formal analysis, Visualization, Writing – original draft. **S. Aalbers:** Investigation, Supervision, Visualization, Writing – review & editing. **C. Sepulveda:** Investigation, Supervision, Funding acquisition, Visualization, Writing – review & editing. **J.L. Valero:** Investigation, Supervision, Writing – review & editing. **O. Sosa-Nishizaki:** Conceptualization, Investigation, Resources, Supervision, Visualization, Writing – review & editing.

Declaration of competing interest

The authors declare the following financial interests/personal relationships which may be considered as potential competing interests: Fajardo-Yamamoto A. reports financial support was provided by National Council on Science and Technology MEXICO.

Data availability

Data will be made available on request.

Acknowledgments

Thanks to the Fisheries Ecology Laboratory members from CICESE for all the comments and support of this manuscript. Mexico's Consejo Nacional de Ciencia *y* Tecnología (CONAYCT) provided a graduate fellowship to AFY (Ref. 26183). We thank all the local fishermen who provided us with information.

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