Evaluation of the Data Available for Bottomfish Stock Assessments in Guam

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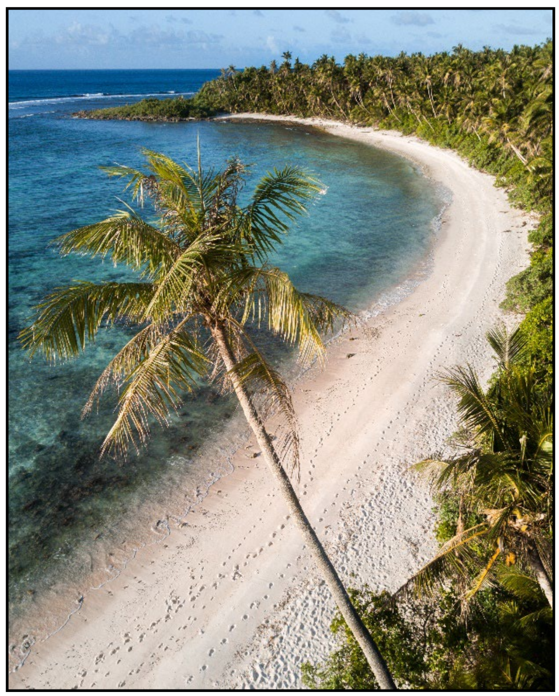

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Executive Summary

We documented all available data on catch, size, catch per unit effort (CPUE), and life history information of the 13 Guam bottomfish management unit species (BMUS) for the benchmark stock assessments, which are anticipated to be completed in 2025 or 2026. We present general descriptions of data sets and data trends available during the writing of this report, which include data through the end of 2021. During the creation of this report, NOAA Fisheries staff engaged with the Guam fishing community and the Guam Department of Agriculture, Division of Aquatic and Wildlife Resources (DAWR) through a series of remote meetings and in-person workshops to thoroughly catalog data sources and understand the Guam bottomfisheries (Iwane et al., 2023). We sought to describe all available data on the Guam BMUS, understanding the stock assessments will likely not include data sources containing limited observations of the BMUS, small sample sizes, short timeseries, and inconsistent or poorly defined methodology.

The DAWR Boat-Based Survey (BBS) has been implemented to monitor catches of bottomfishes, including the 13 BMUS, since 1982. The BBS forms the basis of total catch estimates that are routinely used for management purposes. The voluntary Commercial Purchase Invoice Program, which began in 1982, documents commercial catch and sales to participating fish vendors in Guam and provides a minimum catch estimate to compliment BBS-based catch estimates. Several voluntary self-reporting data collection programs, including the Guam Fishermen's Co-op Fishing Trip Survey (2004–2009) and the recently released CatchIt LogIt Self-Reporting Application Suite are characterized by very limited data coverage and small sample size, and will likely not be informative for the BMUS stock assessments. The DAWR maintains the Shore-Based Survey (SBS) which focuses on shore-based fishing methods and began in 1984. However, the SBS may be of limited utility in stock assessments for BMUS, because shore-based fishing methods do not often catch bottomfishes. Similarly, the NOAA Fisheries Diver Surveys provide very few data on BMUS because SCUBA operations are conducted at maximum 30 m water depths, which is much more shallow than the preferred habitat of the BMUS. The NOAA Fisheries Biosampling Program, which began in 2009, provides records of size (length) composition for all BMUS, though the number of length observations may be small for some BMUS and years. This report also describes several early (pre-1982) DAWR agency reports, independent research projects, and historical accounts dating back to 1967 that may be useful in reconstructing a complete catch history for the Guam BMUS.

We evaluated five criteria to characterize the overall amount and quality of available data for each BMUS in Guam: (1) availability of historical (1967–1981) catch estimates, (2) variability and uncertainty in recent (1982–2021) catch estimates, (3) species occurrence in the BBS, (4) number of individual size observations, and (5) relevance and dependability of life history studies. For each criterion, we defined values or qualitative characterizations to categorize the level of information or usefulness in the available data as either low (red), moderate (yellow), or high (green). Catch estimates and abundance indices (standardized CPUE timeseries) may be challenging to compile for several BMUS due to being rarely recorded in the BBS. Length observations are

generally not available from the BBS due to uncertainty in length composition data introduced by sub-sampling protocols. The PIFSC Biosampling Program may provide the majority of length observations; however, annual sample size is small with high interannual variability for most BMUS. There are several recently published life history studies based on large sample sizes of fish caught in the Mariana Archipelago that will provide dependable growth, maturity, and longevity parameter estimates for several BMUS, but for other BMUS, life history information is greatly lacking.

Overall, we found perhaps only 2 of the 13 Guam BMUS (*Lethrinus rubrioperculatus* and *Pristipomoides auricilla*) have sufficient data to run the more complex integrated or length-based assessment models, owing primarily to the paucity of length measurements. There are likely not enough data to run any assessment models for *P. sieboldii* as this BMUS is rarely recorded in data sources that capture other BMUS. Co-occurrence of a newly described cryptic species (*Etelis boweni*) with *E. carbunculus* in Guam may preclude any stock assessment of this species. Performing stock assessments of the remaining 9 Guam BMUS may require drawing on a range of stock assessment modeling approaches, including catch-only methods, length-based spawner per recruit analysis, or surplus production modeling.

Summary of the data available for 13 BMUS in Guam.

BMUS	Criteria				
	1) Historical Landings Recorded at species level	**2) Recent Landings** CV over years | years with group-identified > 10% total	**3) Species Occurrence** % BBS interviews	**4) Size Observations** Average per year | years with > 50 samples	**5) Life History** Location | sample size | A_{max} % global
Aphareus rutilans	Yes	0.95 | 7	6.1	20 | 1	Mariana | 26 | 44
Caranx ignobilis	No	1.9 | 16	1.9	11 | 0	MHI | 180 | 100
Caranx lugubris	Yes	1.25 | 6	3.8	24 | 2	Mariana | 25 | 100
Etelis carbunculus	Yes	0.86 | 5	9.3	70 | 7	Mariana | 62 | 7
Etelis coruscans	Yes	1.39 | 10	5.6	42 | 4	Okinawa | 768 | 100
Lethrinus rubrioperculatus	No	0.83 | 13	24.4	590 | 11	Mariana | 275 | 100
Lutjanus kasmira	No	0.65 | 13	13.3	99 | 8	Mariana | 33 | 100
Pristipomoides auricilla	Yes	0.79 | 5	12.6	277 | 12	Mariana | 295 | 100
Pristipomoides filamentosus	Yes	1.06 | 5	3.4	21 | 2	Mariana | 217 | 47
Pristipomoides flavipinnis	Yes	1.06 | 5	5.8	51 | 5	Mariana | 57 | 21
Pristipomoides sieboldii	No	2.48 | 13	0.8	31 | 2	Okinawa | 371 | 100
Pristipomoides zonatus	Yes	0.76 | 3	11.9	73 | 8	Guam | 317 | 100
Variola louti	No	0.99 | 4	10.2	88 | 7	Guam | 287 | 93

1. Introduction

Guam is the largest and southernmost Island of the Mariana Archipelago. The total land area is 212 square miles, with a limestone plateau covering the northern region of the island and the southern region consisting of old volcanic hills. The total Guam population was 153,836 in 2020, including approximately 21,700 U.S. military personnel and their families (U.S. Census Bureau, 2022; U.S. Defense Department, 2022). Fishing in Guam is important for contributing to the subsistence needs of the people, preserving history and identity, and maintaining cultural practices (Allen and Bartram, 2008).

The deep-slope fishes of Guam include snappers (Lutjanidae), groupers (Serranidae), emperors (Lethrinidae), and jacks (Carangidae). Collectively referred to as “bottomfishes,” these species are caught by a combination of recreational, subsistence, and small-scale commercial fishing operations using hook and line with electric or manually operated reels, depending on fishing depth. Fifty-eight (58) unique vessels are known to have engaged in bottomfishing in 2021, with an estimated catch of 54,217 lb (WPRFMC 2022). Most bottomfishing vessels are less than 25 feet in length and target shallower bottomfish species for recreational or subsistence purposes. Some of these vessels, as well as most larger vessels, also target the deeper bottomfish species at the offshore banks and other areas around Guam where deep bottomfish habitat occurs.

Bottomfishes in Federal waters (3 to 200 miles from shore) are currently managed by the Western Pacific Regional Fishery Management Council (WPRFMC) under the Fishery Ecosystem Plan for the Mariana Archipelago (FEP; WPRFMC, 2009). The FEP was preceded by the 1986 Fishery Management Plan for the Bottomfish and Seamount Groundfish Fisheries of the Western Pacific Region, which named 19 bottomfish management unit species (BMUS) across Guam, Hawaiʻi, and American Samoa (WPRFMC, 1986). The 2009 FEP specified 205 species or families of fish and invertebrates, including 17 species of bottomfish requiring management with catch limits or other regulations. However, most species within the FEP were reclassified as “ecosystem component species” in 2019, leaving only 13 BMUS that required management by the WPRFMC in the Mariana Archipelago (84 FR 2767). These 13 species (Table 1-1) were retained as BMUS because they were considered by local fishers and fisheries scientists to be most in need of conservation and management.

The Guam BMUS were initially assessed as a complex (i.e., all 13 BMUS species were combined) using an informal index-based assessment method. For this approach, annual nominal catch rates as the total estimated lb of BMUS caught each year divided by the total estimated number of hours fished each year were compared to an established indicator level equal to 50% of average nominal catch rates over 1982–1984. According to these early assessment methods, the BMUS complex was believed to have been experiencing overfishing from the mid-1990s through 2000, and furthermore, was overfished in 1997 and 1998 (Moffitt et al., 2007). The first formal stock assessment of Guam bottomfishes was completed in 2007 (Moffitt et al., 2007). This assessment improved upon the index-based assessment method and relied on a Bayesian surplus production model which accounted for both process and observation errors and therefore captured parameter uncertainty for status determinations. The

BMUS complex was determined to be not overfished and not experiencing overfishing in 2005 (Moffitt et al., 2007). The 2012 and 2016 assessment updates used a similar approach as the 2007 assessment, with additional data. These assessments also concluded the BMUS complex was not overfished and not experiencing overfishing in 2010 (Brodziak et al., 2012) and 2013 (Yau et al., 2016). The most recent assessment was completed in 2019 and used a similar Bayesian surplus production model as the previous assessments and incorporated improvements in data and modeling methodology as recommended by the Western Pacific Stock Assessment and Review process (WPSAR; Langseth et al., 2019). The 2019 assessment concluded that in 2017, the Guam BMUS complex was in an overfished state, but was not experiencing overfishing.

The next benchmark stock assessment for the Guam BMUS is expected to be completed and undergo an independent review process in 2025 or 2026, following the established WPSAR timeline. One key improvement for this new benchmark assessment will be to consider single-species assessment models following the WPSAR panel recommendations from the 2016 assessment (Chaloupka et al., 2015). Specifically, the WPSAR panel recommended the exploration of length- and life history-based single-species modeling approaches, as well as splitting the BMUS into shallow- and deep-species complexes. Complex-level (aggregated across multiple species) assessments are limited to surplus-production models, which mainly rely on catch and catch per unit effort (CPUE) data. In contrast, single-species assessments are more flexible, ranging in complexity from simple length-based per-recruit analyses to more advanced age-structured integrated models, including within the Stock Synthesis framework (Methot and Wetzel, 2013).

In this report, we document all available data on catch, size, CPUE, and life history information of the 13 Guam BMUS as a preliminary step to compile data for the upcoming assessment. We present general descriptions of data sets and data trends available during the writing of this report, which include data through the end of 2021. Year 2022 data will be available and incorporated into the stock assessments that will be completed in 2024. During the creation of this report, NOAA Fisheries staff engaged with the Guam fishing community and the Guam Department of Agriculture, Division of Aquatic and Wildlife Resources (DAWR) through a series of remote meetings and in-person workshops to thoroughly catalog data sources and understand the Guam bottomfisheries. A detailed report on the January 2023 in-person workshops is available in Iwane et al. (2023), and several additional data sets discussed during the workshops have been incorporated herein. We sought to describe all available data on the Guam BMUS, with the understanding that the stock assessments will likely not include data sources with limited observations of the BMUS, small sample size, short timeseries, or inconsistent or poorly defined methodology. We conclude our report with a discussion of the likely assessment methods for each of the BMUS in the 2024 stock assessments, based on the data available, including the feasibility of using advanced age-structured single-species models.

Table 1-1. Mariana Archipelago bottomfish management unit species (BMUS).

Species	Local names	Hawaiian and English common names	Code
Aphareus rutilans	Maroobw, lehi	Lehi, rusty jobfish	APRU
Caranx ignobilis	Mamulan, tarakitu, etam	‘Ulua aukea, giant trevally	CAIG
Caranx lugubris	Tarakiton attelong, orong (tarakito, tarakiton atilong, yorong)	‘Ulua la‘uli, black trevally, black jack	CALU
Etelis carbunculus	Buninas agaga’, falaghal moroobw	Ehu, ruby snapper	ETCA
Etelis coruscans	Buninas, taighulupegh	Onaga, deepwater longtail red snapper	ETCO
Lethrinus rubrioperculatus	Mafute’, atigh	Redear, redgill, spotcheek emperor	LERU
Lutjanus kasmira	Funai, saas	Ta‘ape, bluestripe snapper	LUKA
Pristipomoides auricilla	Buninas, falaghal-maroobw	Yelloweye / gold flag snapper	PRAU
Pristipomoides filamentosus	Buninas, falaghal-maroobw	Opakapaka, crimson jobfish	PRFI
Pristipomoides flavipinnis	Buninas, falaghal-maroobw	Yelloweye opakapaka, golden eye jobfish	PRFL
Pristipomoides sieboldii	Buninas, falaghal-maroobw	Von Siebold’s snapper	PRSE
Pristipomoides zonatus	Buninas rayao amiriyu, falaghal-maroobw	Gindai, oblique-banded snapper	PRZO
Variola louti	Gadau matingon/bwele	Yellow-edged lyretail grouper	VALO

2. Boat-Based Creel Survey

The Guam Department of Agriculture, Division of Aquatic and Wildlife Resources (DAWR) began a creel survey to monitor fisheries catch and effort in the early 1960s (DAWR, 1963a). These early surveys focused primarily on nearshore fishing activity but some bottomfishers were included in interview data beginning in 1965 (DAWR, 1965). The survey methodology was modified several times over the years and was largely standardized by 1982 when DAWR began coordinating with the Pacific Islands Fisheries Science Center (PIFSC) Western Pacific Fisheries Information Network (WPacFIN) to improve data collection, processing, and storage, and establish the Boat-Based Creel Survey (BBS) as it continues today. Detailed methodology of the BBS, including survey design, field data sheets, and specific guidance for field survey technicians, is documented in Oram et al. (2014) and Jasper et al. (2016).

The BBS includes two data streams: (1) interviews of fishers returning from fishing with survey of their catch, and (2) observations of fishing boats leaving and returning to port allowing estimates of the number of boat-based fishing trips occurring annually. Together, these two data streams are used by NOAA Fisheries to estimate annual landings for management purposes. BBS creel interviews may also provide catch per unit effort (CPUE) timeseries and fish length or weight compositions for stock assessments.

2.1 Creel interviews

DAWR survey teams visit the three main fishing ports of Guam a minimum of 8 randomly selected days per month: 4 weekdays and 4 weekend/holidays. These access-point surveys take place twice during each survey day (once during the morning shift, approximately 0500–1200, and once during the evening shift, approximately 1600–2400). The busiest boat harbor, Agana Boat Basin, is surveyed twice as frequently (2 weekdays and 2 weekend/holidays per month) as Agat Harbor and Merizo Pier (Figure 2-1). However, Merizo Pier and Agat Harbor were not surveyed before 1988 and 1994, respectively, and the first years with full data for these ports are consequentially 1989 and 1995 (Figure 2-2).

Participation in BBS interviews is voluntary. Interviewers collect information on effort (hours fished, number and types of fishing gear, number of fishers/people on board, whether the trip was chartered, and boat capabilities such as engine type, or use of GPS, fish finder, and powered reels), areas fished (Figure 2-1), environmental conditions (weather, wind direction, wind speed, and sea state), economic information (percent of catch sold, identity of the buyer, and trip expenditures such as fuel, ice, and bait), bycatch (species, number, condition, and sizes/weights of fish that were thrown back), whether interactions with sharks occurred, and catch. Catch information includes total catch per species in numbers and weight, and may also include individual fish length or weight observations.

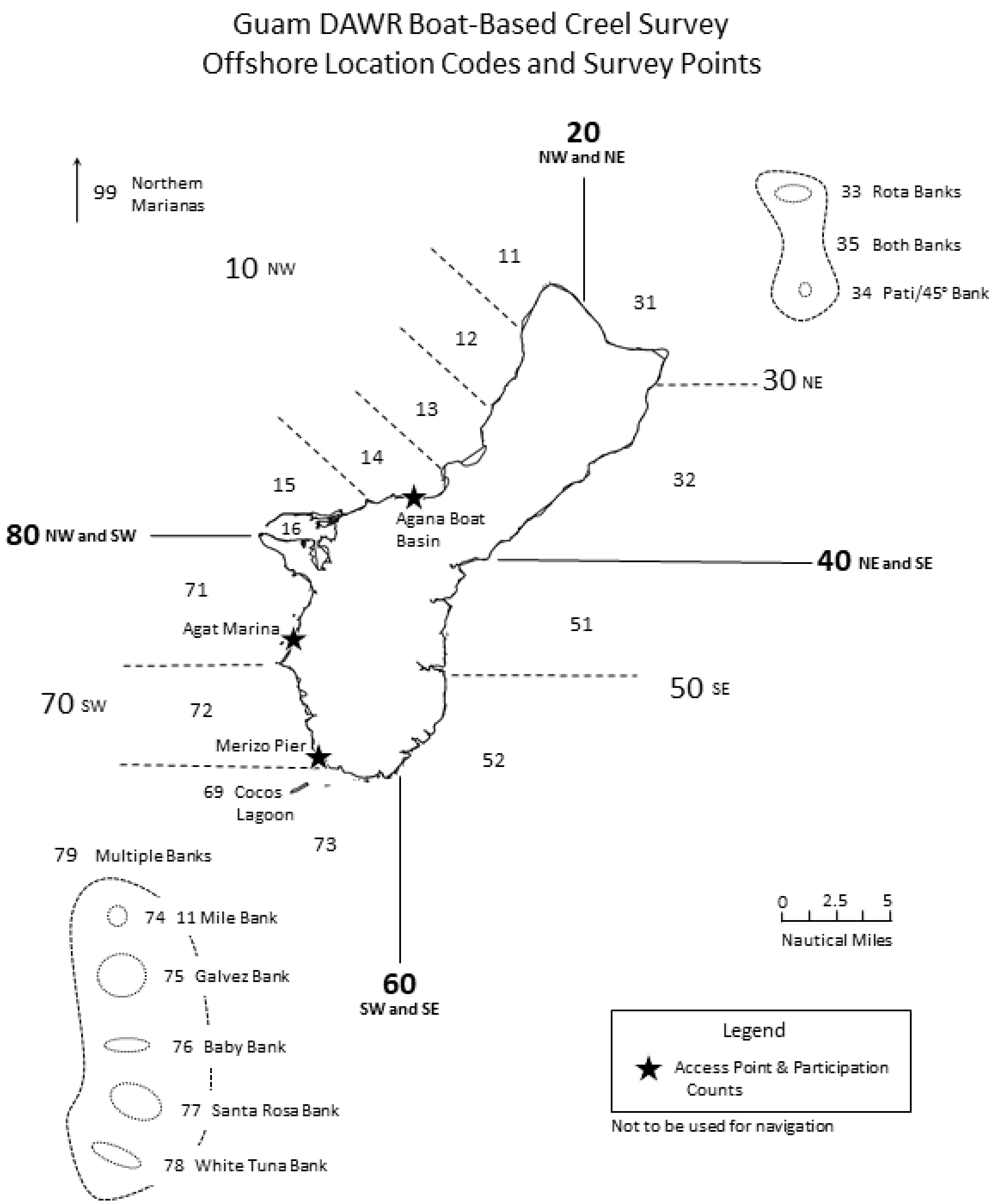


Figure 2-1. Map of the BBS survey ports and offshore fishing area codes.

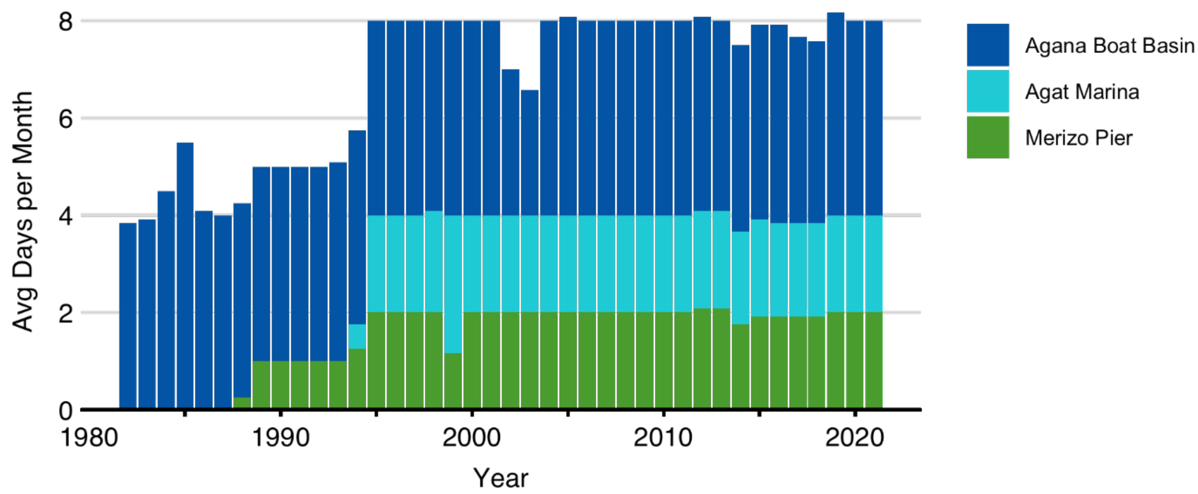


Figure 2-2. Average BBS survey days per month by port and year. Creel interview and participation data are collected jointly on each survey day.

2.1.1 Temporal trends in effort and species catch by gear

There were an average of 833 BBS interviews collected per year from 1982–2021, ranging from 350 interviews in 2020, when both fishing and survey activity were reduced during the COVID-19 pandemic, to 1,617 interviews in 1995 (Figure 2-3). There were 25 different fishing gears recorded in the BBS. The majority of interviews in the BBS timeseries were for trolling (72.8% of all interviews). Bottomfishing and spearfishing, which were the 2nd and 3rd most common gears in the data set, accounted for 17.6% and 5.3%, respectively, of all interviews. Approximately 85 interviews per year (range 32–151) included identified bottomfish management unit species (BMUS); bottomfishing was the predominant gear type, accounting for 91% of all interviews containing BMUS (Figure 2-4). Occurrences of each BMUS by gear varied among species (Figure 2-5), although bottomfishing was the predominant gear type for all BMUS. In some years, the majority of observed *C. ignobilis* by weight was from spearfishing and trolling interviews. *V. louti* were recorded in spearfishing interviews peaking in the 1990s and early 2000s. Because identified BMUS were mostly encountered by bottomfishing gear, the remainder of this report will focus on bottomfishing interviews only. However, estimated annual landings of BMUS from all BBS gear types are included in the catch section of this report (Section 2.3).

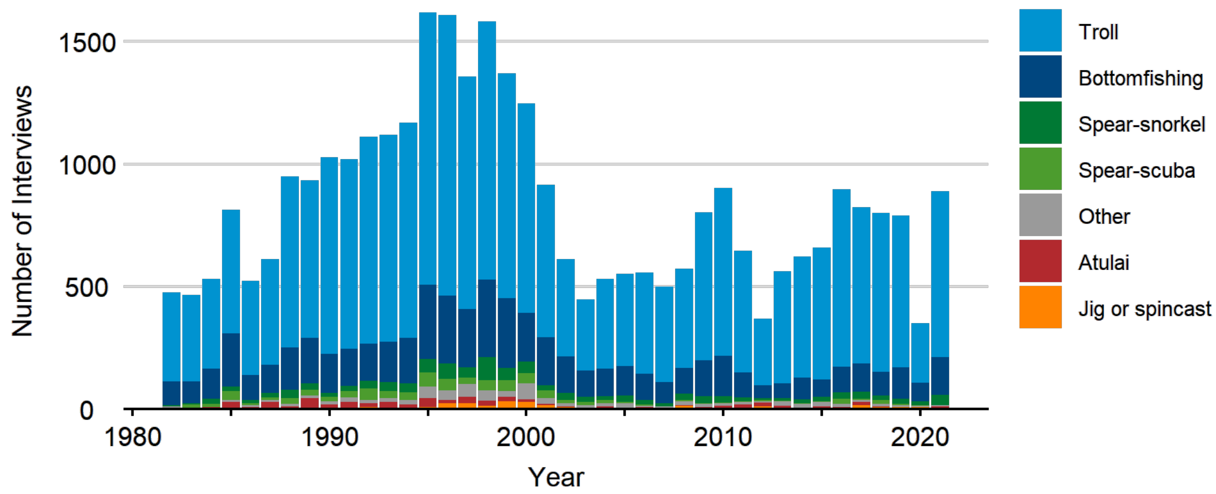


Figure 2-3. Total number of BBS interviews per year by fishing gear.

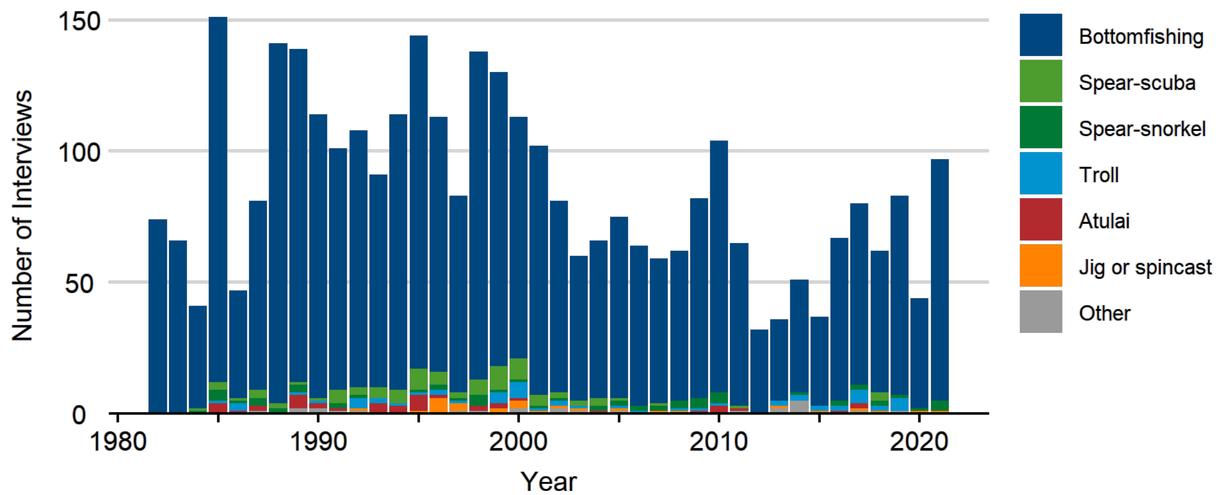


Figure 2-4. Number of BBS interviews per year by fishing gear that recorded identified BMUS.

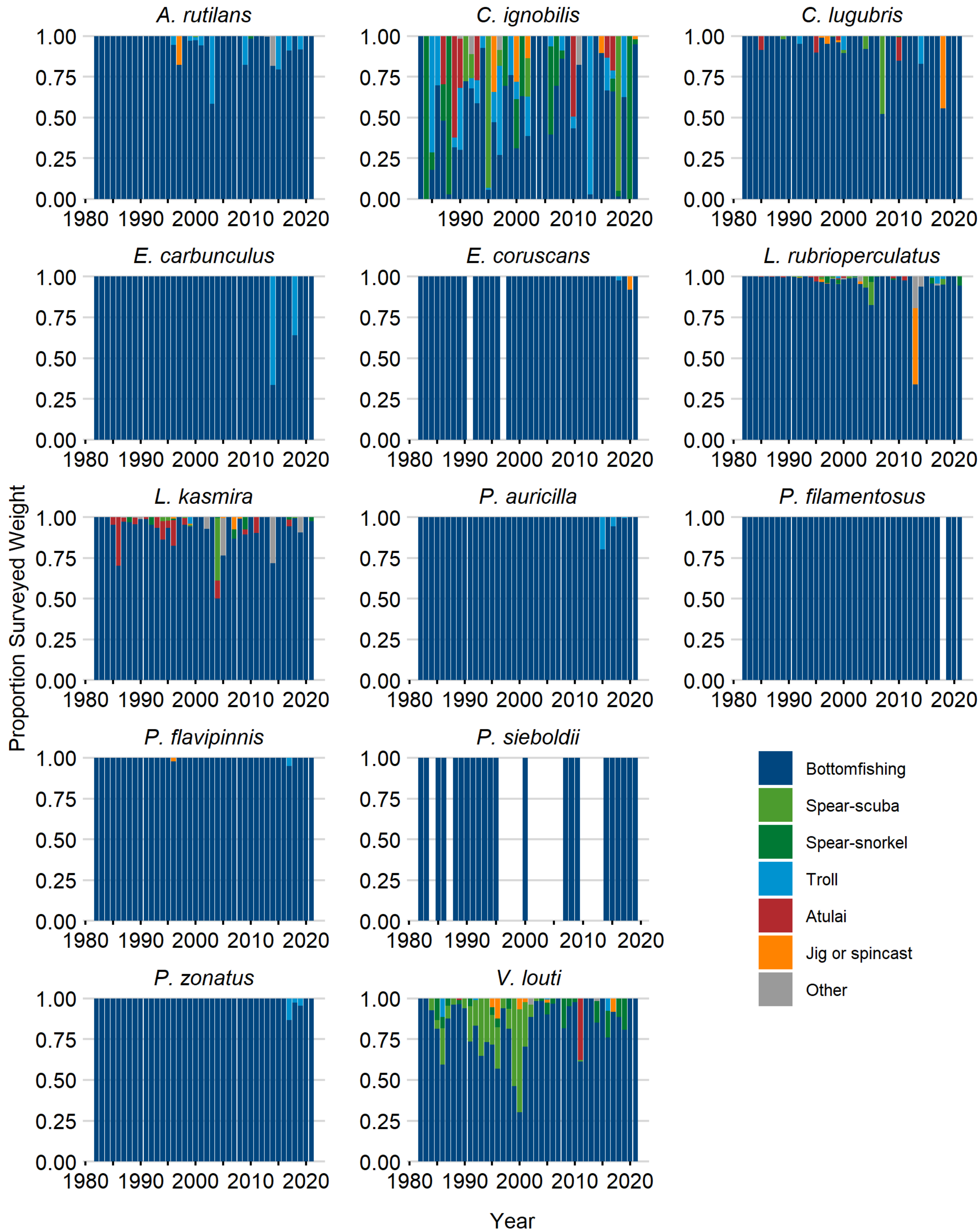


Figure 2-5. Proportion of BBS annual surveyed catch weight for each BMUS by fishing gear (identified to species only).

During creel survey interviews, fishers reported the area where they fished generally by quadrant or sometimes by cardinal directions or more specific areas (see map, Figure 2-1). Occasionally, area fished information is not available, fishing occurred in multiple quadrants, or fishing occurred in the Commonwealth of the Northern Mariana Islands. There has been a general north to south shift in reported areas fished within BBS creel survey interviews over time (Figure 2-6). These changes generally agree with the addition of the more southern intercept ports to the BBS protocol: Merizo Pier in 1988 and Agat Marina in 1994 (Figure 2-7).

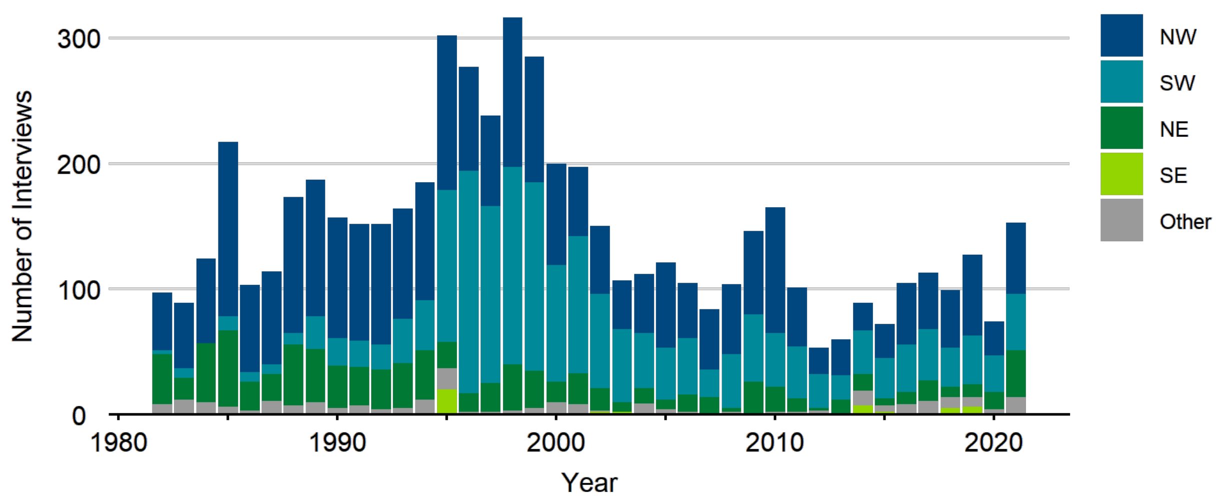


Figure 2-6. Number of BBS interviews per year by area for bottomfishing gear.

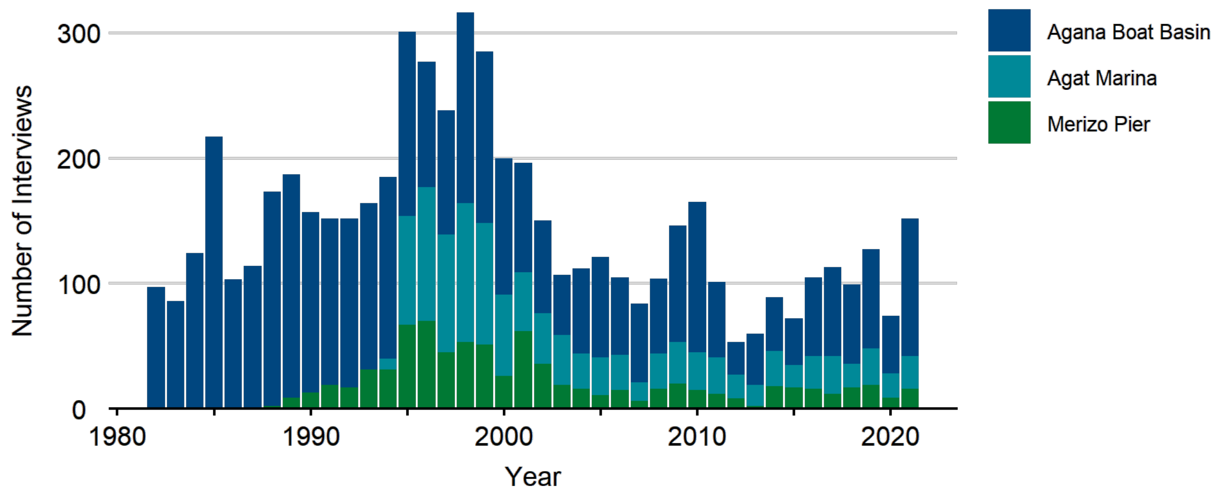


Figure 2-7. Number of BBS interviews per year by access point (bottomfishing gear). There were also 4 interviews recorded for Seaplane Ramp and 1 interview for Ylig Bay (not shown).

2.1.2 Species surveyed

There were 376 species and species groups (e.g., shallow bottomfish, assorted bottomfish, deep bottomfish, Lethrinidae, assorted reef fish, deep snapper, and Carangidae, etc.) identified in interviews for bottomfishing during 1982–2021. The most commonly recorded species were *L. rubrioperculatus*, *E. coruscans*, *P. auricilla*, and *E. carbunculus*, accounting for combined 28% of total surveyed weight (Table 2-1). *P. sieboldii* was the least recorded BMUS, comprising only 0.3% of total surveyed bottomfishing catch by weight.

Table 2-1. BBS surveyed catch by species (as percent total weight) from bottomfishing 1982–2021. Asterisks (*) denote BMUS.

Species	Percent Surveyed Catch by Weight
**Lethrinus rubrioperculatus*	9.9
**Etelis coruscans*	9.1
Unspecified shallow bottomfishes	7.4
**Pristipomoides auricilla*	5.2
**Etelis carbunculus*	3.8
Aprion virescens	3.6
Epinephelus fasciatus	3.2
**Pristipomoides zonatus*	3.1
**Aphareus rutilans*	2.9
Gymnosarda unicolor	2.5
**Caranx lugubris*	2.1
Unspecified bottomfishes	2.1
Lethrinus xanthochilus	1.8
**Pristipomoides flavipinnis*	1.8
**Variola louti*	1.7
Lethrinus obsoletus	1.7
Lethrinus harak	1.7
**Lutjanus kasmira*	1.5
**Pristipomoides filamentosus*	1.3
Sphyraena barracuda	1.3
Unspecified deep bottomfishes	1.3
Seriola dumerili	1.3
Carangoides orthogrammus	1.2
Caranx melampygus	1.2
Cephalopholis sonnerati	1.1
**Caranx ignobilis*	1.1
Lethrinus olivaceus	1.1
Sphyraena qenie	1.0
Lutjanus bohar	1.0
**Pristipomoides sieboldii*	0.3
All Other Species and species groups (*N* = 346)	20.3

2.1.3 BMUS species identification and occurrence

In BBS interviews, catch weight by species ('surveyed' catch weight) is obtained by multiplying the number of individuals of a given species caught by the average weight of those individuals. A subsample of all individuals may be used to calculate this average weight, and their weight can be estimated following three possible procedures: actual (individuals are directly weighed), calculated (individual lengths are measured and converted to weight estimates through pre-determined length-weight relationships), or estimated (weights are roughly approximated, for example, by estimating the total weight of fish that a cooler can hold). The practice of estimating catch weight of BMUS in bottomfishing interviews has been nearly absent since 2015; however, almost 60% of total surveyed catch of BMUS was estimated in 1984 and exceeded 20% in 14 additional years (Figure 2-8).

Catch is sometimes recorded in terms of common name groups or families in the BBS interview data which could possibly include BMUS. In decreasing order, by total surveyed weight in bottomfishing interviews over the entire timeseries, these group identifiers are: shallow bottomfish, assorted bottomfish, deep bottomfish, Lethrinidae, deep snappers, Carangidae, Lutjanidae, and shallow snappers. Group-level identifications have been used for approximately 4% of surveyed catch from bottomfishing in recent years (2017–2021 average), but averaged over 17% of catch from 1982–2000 (Figure 2-9). In 1984, 72% of all surveyed catch was identified only to the group level.

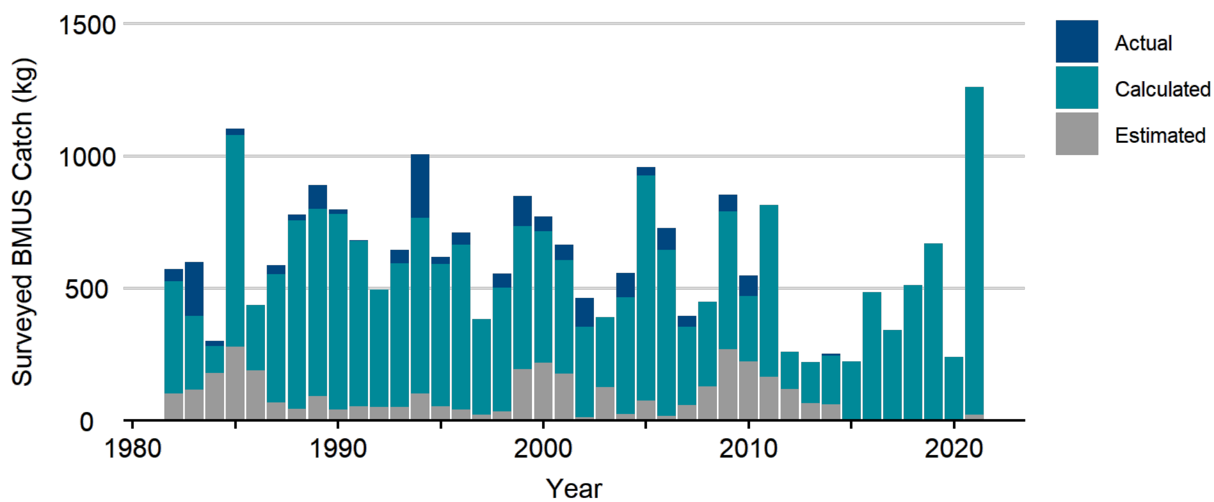


Figure 2-8. Surveyed catch (kg) of BMUS in BBS bottomfishing interviews by weight measurement approach.

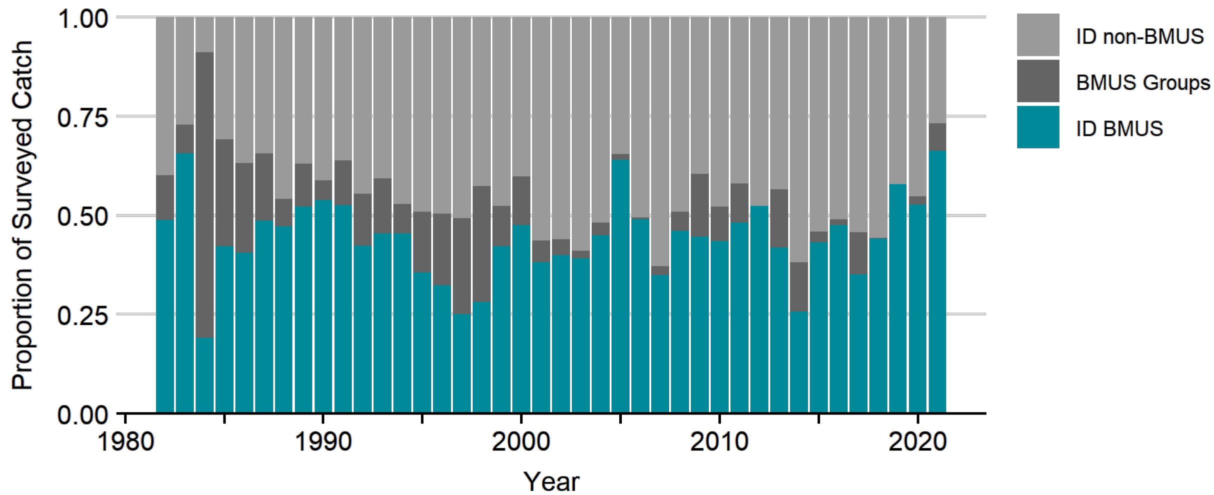


Figure 2-9. Proportion of BBS surveyed catch (weight) by level of identification and year for bottomfishing gear only.

The proportion of interviews for bottomfishing gear that recorded each BMUS varied by species (Figure 2-10). *L. rubrioperculatus* was the most frequently encountered BMUS, observed in an average of 24% of all interviews annually. In contrast, *P. sieboldii* was not recorded at all in 18 of the 40 years of the BBS and had an overall annual occurrence in < 1% of interviews. *C. ignobilis* and *P. filamentosus* were also relatively rare, with average annual occurrence of 1.9 and 3.4% of interviews, respectively. Although catch by weight of *C. ignobilis* is comparable among interviews of spear, troll, and bottomfishing gears (Figure 2-5), this species is not frequently encountered in any gear type and was recorded in only 1.3% of spearfishing, 0.1% of troll, and 2.8% of atulai fishing interviews. *V. louti* was recorded in 4.8% of all spearfishing interviews, but was not recorded at all in 9 of the 40 years of survey data.

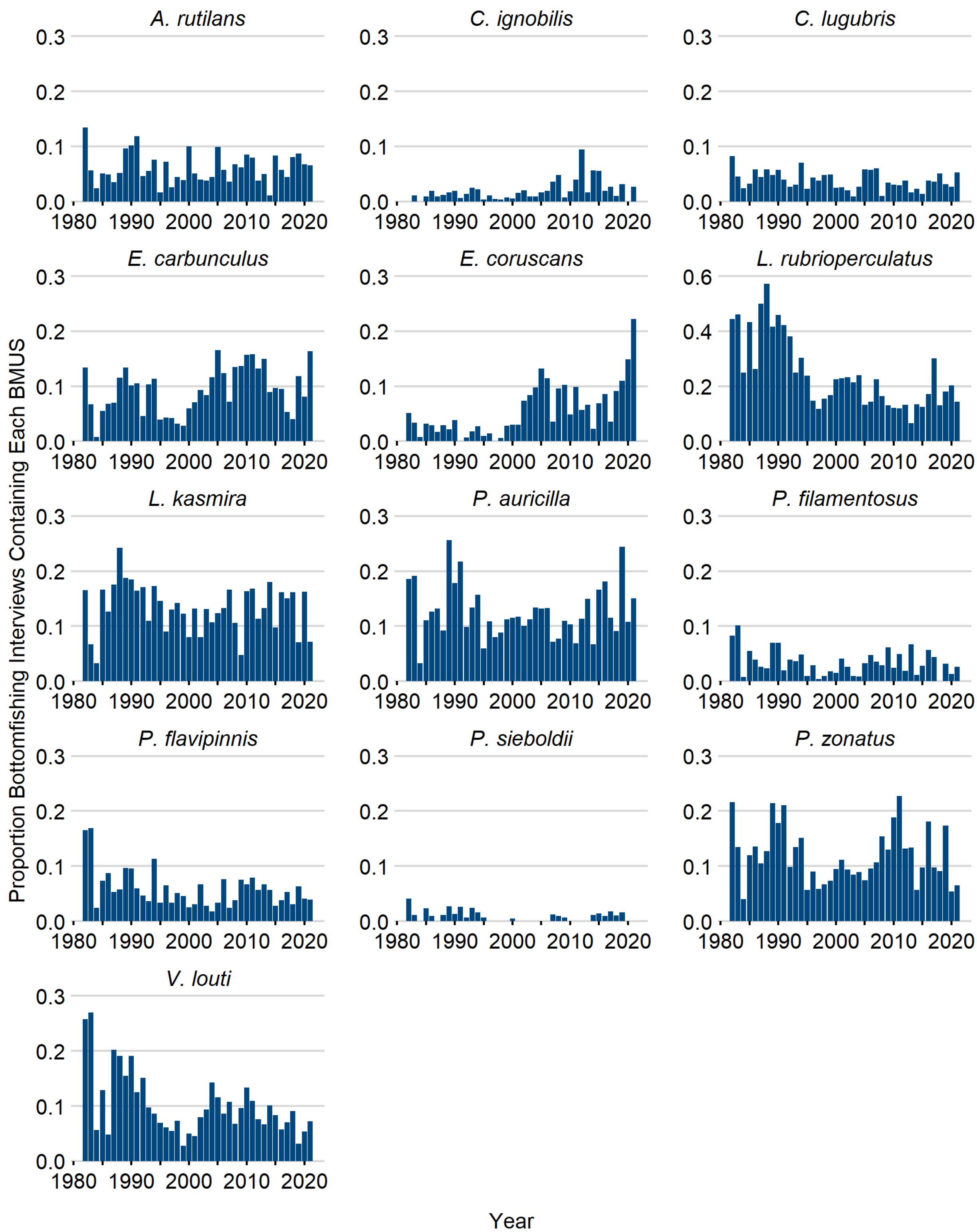


Figure 2-10. Proportion of total BBS bottomfishing interviews by year positive for each BMUS.

2.1.4 Size data

During the BBS interviews, individual fish were sometimes measured, most often in terms of length. However, interview protocols regarding the number of individuals per species that should be measured have changed over the timeseries of the BBS and specific guidance is vague or contradictory on which individuals of a species should be selected for measurement. As a result, for some BMUS, the majority of length measurements for some BMUS come from interviews where not every fish was measured, and it cannot be assumed the fish selected for measurement were an accurate representation of the sizes of all fish of a species from that fishing trip. In other words, it is possible that large individuals were more often measured than smaller individuals, or vice-versa. The number of fish lengths gathered from interviews (1982–2021) where every individual of a species was measured ranged from 48 *P. sieboldii* (average 3.4 per year) to 1,595 *L. rubrioperculatus* (average 39.9 per year). The number of individual fish lengths for each BMUS also varied across years, with zero length observations for a given species in some years (Figure 2-11).

Frequency plots of length observations (fork length, FL, in cm) pooled from complete BBS catch records over 2017–2021 are generally difficult to interpret due to small sample sizes (Figure 2-12). The few *E. carbunculus* between 70 and 95 cm FL were likely a separate species, *Etelis boweni*, which has only recently been described (Andrews et al., 2021).

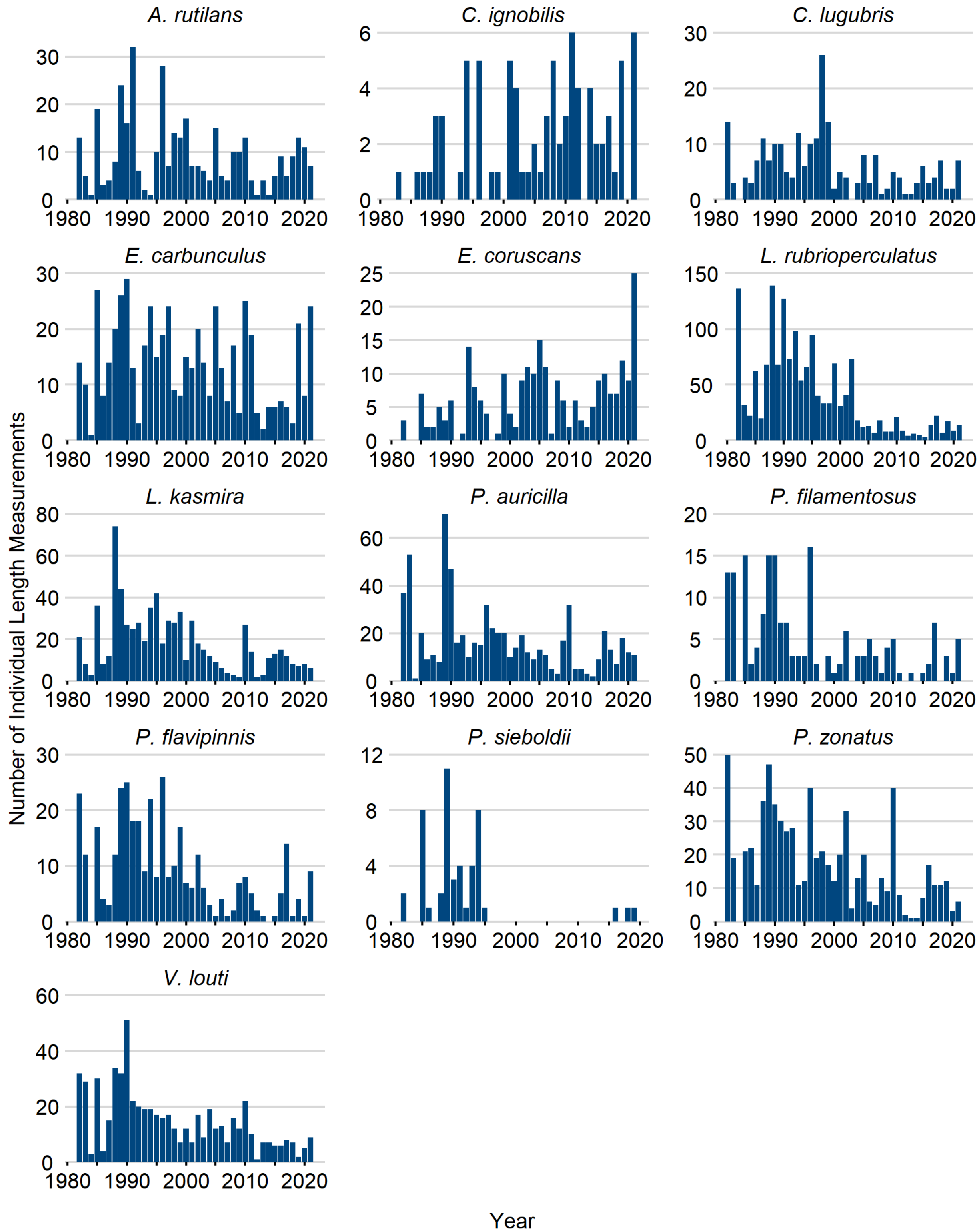


Figure 2-11. Number of BMUS individuals with length observations from bottomfishing BBS interviews where every individual of the species was measured.

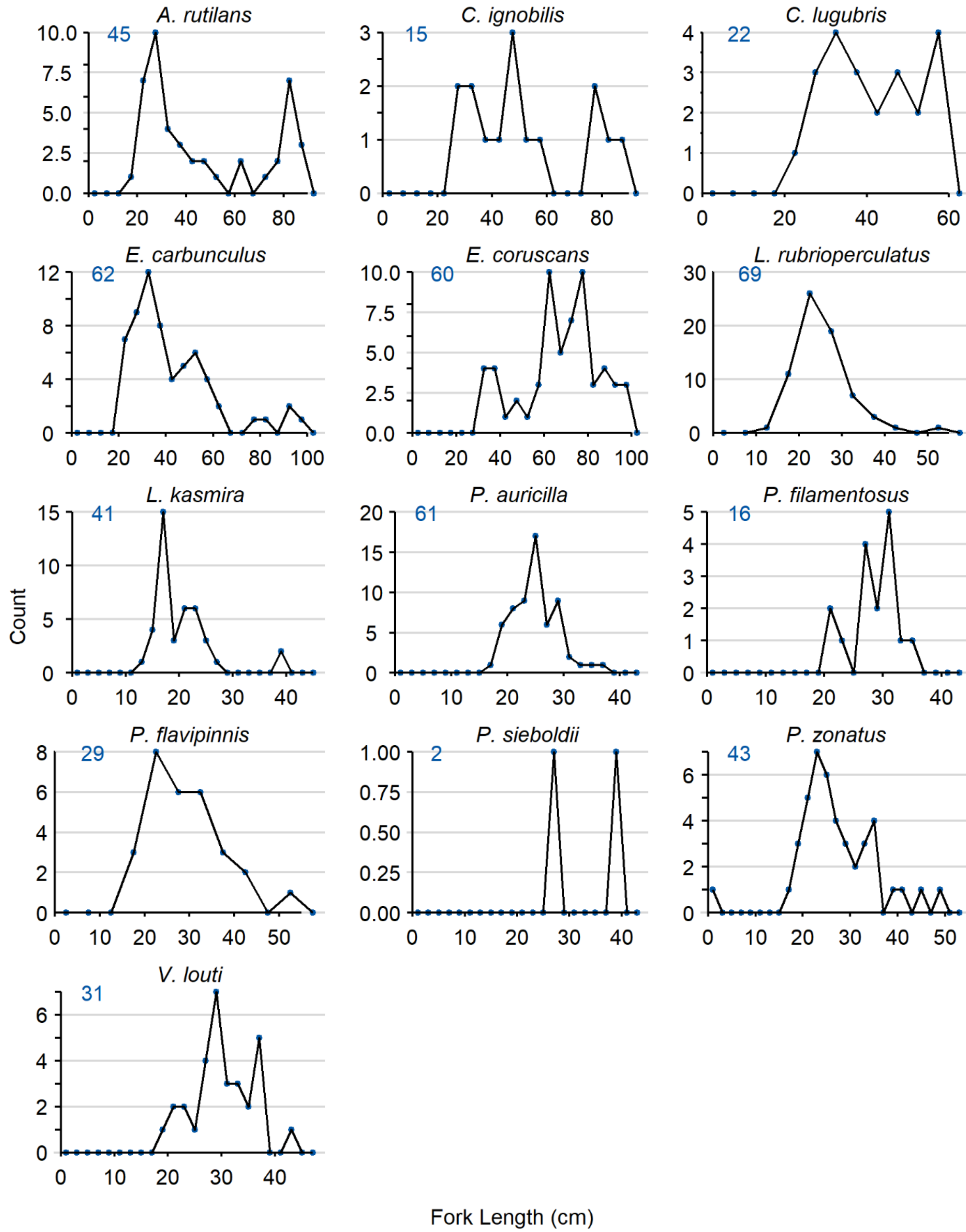


Figure 2-12. BMUS length frequencies recorded in complete BBS catch records of bottomfishing trips over 2017–2021. The number of fish measured is included on each plot.

2.1.5 BMUS disposition

The amount of surveyed catch weight of all BMUS combined that was reported as 'sold' in BBS interviews of bottomfishing trips was highly variable from year to year, but has somewhat decreased over the timeseries from 28% in 1982–1991 to 17% 2012–2021 (Figure 2-13). By species, the percent of catch weight reported sold is also highly variable by year. Overall, *C. ignobilis* and *V. louti* were generally not sold (4% and 13%, respectively, of total surveyed catch weight by species 1982–2021). *E. coruscans*, *C. lugubris*, and *A. rutilans* were the most often sold species (42%, 39%, and 37%, respectively, of total surveyed catch weight by species 1982–2021).

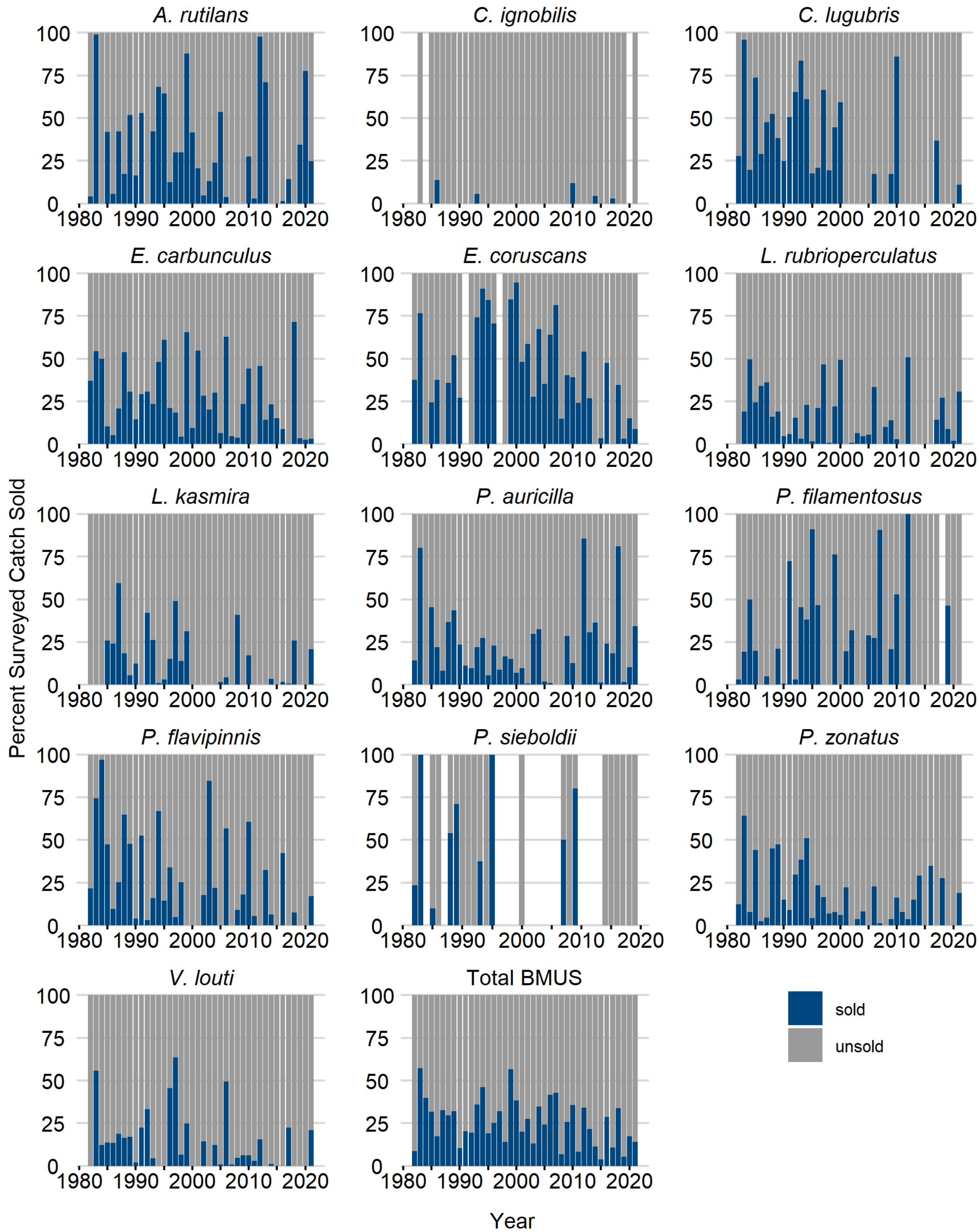


Figure 2-13. Percent of surveyed BMUS catch by weight reported sold in BBS interviews of bottomfishing trips 1982–2021.

2.1.6 Vessels participating

Approximately 1,300 unique vessels were interviewed regarding bottomfishing trips in the BBS from 1982–2021. Of those vessels, 1,006 had bottomfishing trips with identified BMUS or unidentified species groups that could include BMUS, e.g., deep snappers, Lutjanidae, bottomfish, etc. There were 910 unique vessels that caught species-identified BMUS on bottomfishing trips between 1982–2021.

2.2 Participation

DAWR survey teams collected participation data reflecting the number and identity of fishing trips occurring on each survey day. These data were collected during the same access-point surveys as the BBS interviews (Section 2.1). While on site at one of the three surveyed ports, surveyors logged the departure and return times, boat name, and fishing and charter status of each active vessel.

It is known that some boat-based fishing trips operated outside of the three surveyed ports. Supplemental data were collected during the Shore-Based Creel Survey (Section 3) to quantify the relative occurrence of trips outside to within the surveyed ports. During the land-based participation survey, which occurred during morning (starting at 0630) and evening (starting at 1900) shifts on two weekdays and two weekend/holidays per month, all encountered vehicle trailers were logged. Based on past experience, it was assumed that all vehicle trailers are associated with fishing trips. There is the possibility that some of the trailers counted were not engaged in fishing activity; however, since this information is used in a relative manner, as long as no systematic change has occurred at a specific port, no bias should be introduced.

Total annual fishing effort, in number of trips, was estimated for surveyed ports by multiplying the average fishing trips per survey day from participation data by the number of days per year within each expansion domain (port, gear type, day type, and charter status). The number of trips outside the survey ports was estimated by multiplying the annual fishing effort at the representative ports (Agat Marina and Merizo Pier, which are believed to have trailer-launched fishing activity at a constant proportion to such activity at the unsurveyed areas) by the ratio of vehicle trailer counts outside the surveyed ports to within the representative ports. There were also adjustment factors for trips where either the fishing status or gear were unknown (Ma et al., 2022).

The number of fishing trips per year logged in participation count surveys ranged from 531 at the start of the BBS in 1982 to 3,313 in 1999 (Figure 2-14). There was a general trend of steadily increasing logged trips from 1982 to 1999, followed by a 58% drop from 2000 to 2003. However, in interpreting these numbers, it must be noted the number of participation survey days per month has not remained constant over the period. There were roughly 4 survey days per month from 1982 to 1988, followed by 5 per month from 1989 to 1994 when Merizo Pier was added, and finally 8 per month since 1995 when Agat Marina was added (Figure 2-2). This does not change the interpretation of the drop in fishing trips from 2000–2003, but does change the scale of increase in per-survey day participation counts from 1982–1995. Since 2003, the number of fishing trips logged has exhibited high variability amid a gradual increase, with the exception of a low year in 2012. In the first five years since the minimum in 2003, the average number of logged trips per year was 1,623, with a slight increase to 1,939 logged trips per year averaged over the most recent five years, 2017–2021.

When the participation survey counts were expanded to produce an estimate of total annual fishing trips, similar trends in total fishing effort held true. Figure 2-15 shows the estimated total annual fishing trips since 1982, again beginning with the minimum of 7,082 trips per year in the first survey year and attaining its maximum of 30,980 trips in 1999. Trolling has always been the dominant fishing gear, accounting for 59% of all trips over the years. Bottomfishing was the next most common gear type, ranging from 15.8% to 32.6% of trips per year (Figure 2-16). The estimated number of bottomfishing trips per year ranged from 1,530 in 1982 to 9,814 in 1999 (Figure 2-17). Barring a spike in bottomfishing activity from 1995–2001 when there were an average of 8,304 trips per year, background levels have been relatively constant at about 2,500 trips per year. Spearfishing may also have accounted for catch of some BMUS, though it was a relatively minor fishing method with an average of 1,540 trips per year, or 9.4% of all trips.

The estimated total annual fishing trips can also be divided by type of day, charter status, and port. Nearly half (47.3%) of all trips occurred over weekend/holidays, signifying a greater number of trips per day on weekend/holidays than weekdays (Figure 2-18). Only 15.6% of trips were chartered, including a period of relatively high charter activity (21.8% of trips) over the 1990s (Figure 2-19). Over the most recent five years, from 2017 to 2021, only 7.4% of trips were chartered. Lastly, there was an unequal distribution of total annual fishing trips across the surveyed and other ports (Figure 2-20). Over the years that all three presently surveyed ports have been fully included in the BBS (1995–present), Agana Boat Basin served 44.3% of trips, Agat Marina served 29.8%, Merizo Pier served 13.7%, and other ports served 12.2%. These proportions have remained relatively constant since 1995, although activity from other ports was lower from 2002–present.

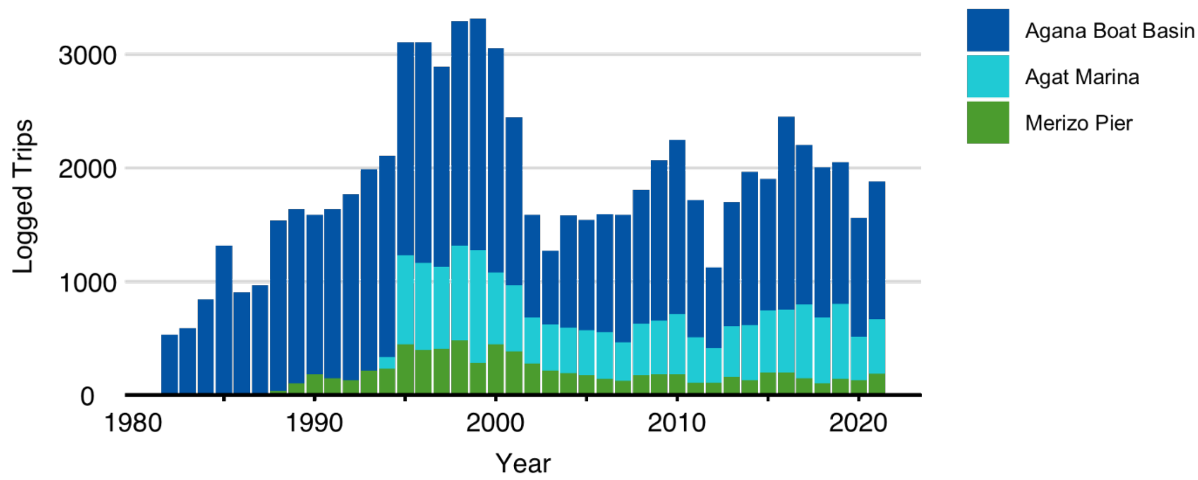


Figure 2-14. Participation count observed trips per year by port.

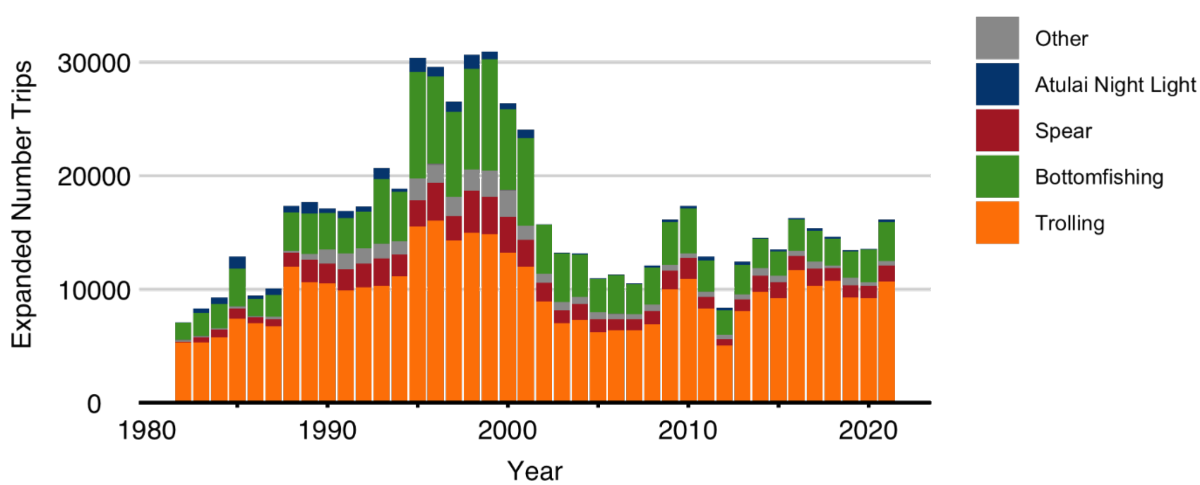


Figure 2-15. Annual number of trips by gear expanded from the BBS.

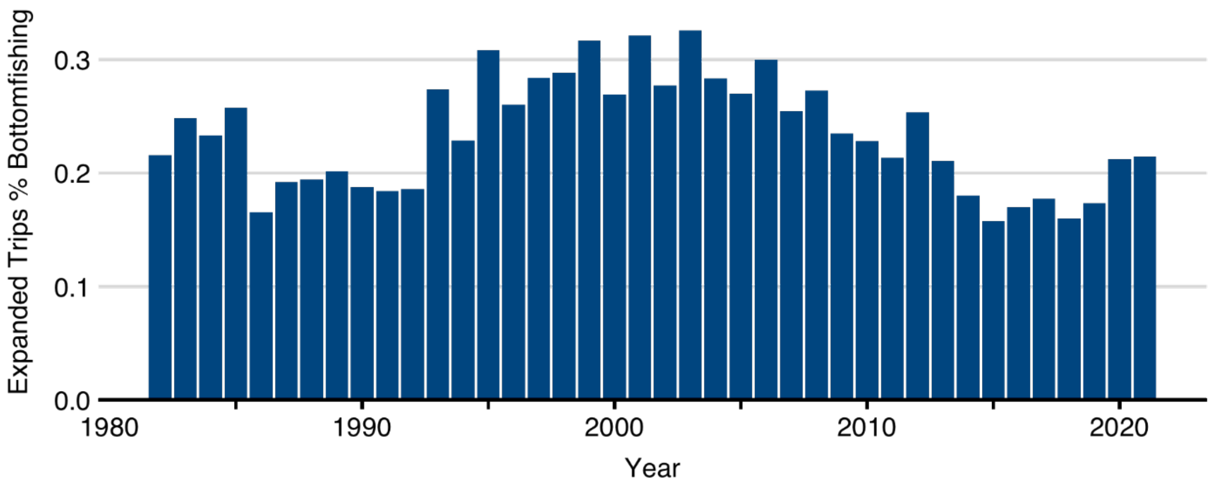


Figure 2-16. Annual percentage of total estimated trips that were bottomfishing.

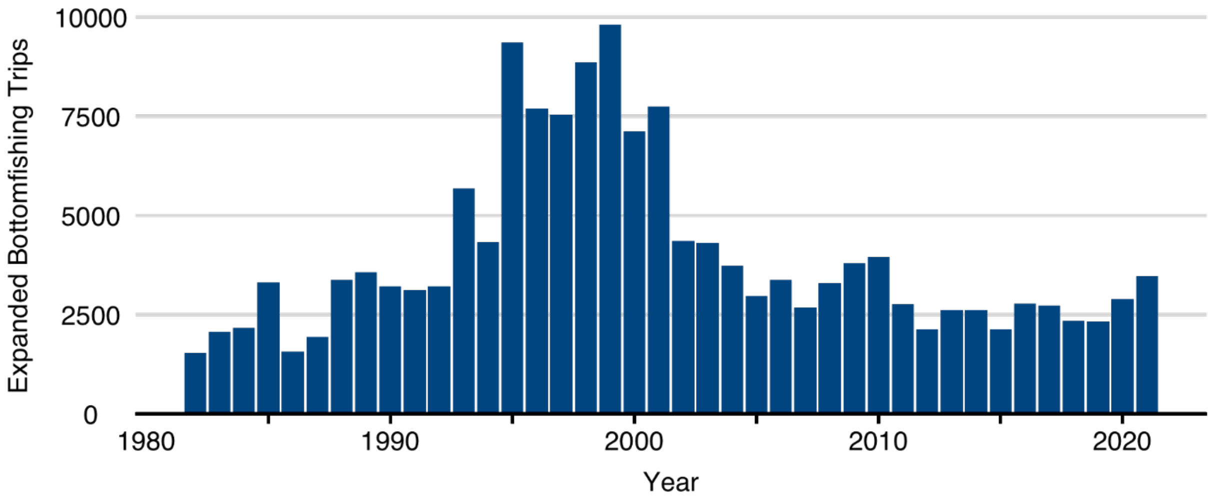


Figure 2-17. Estimated bottomfishing trips per year.

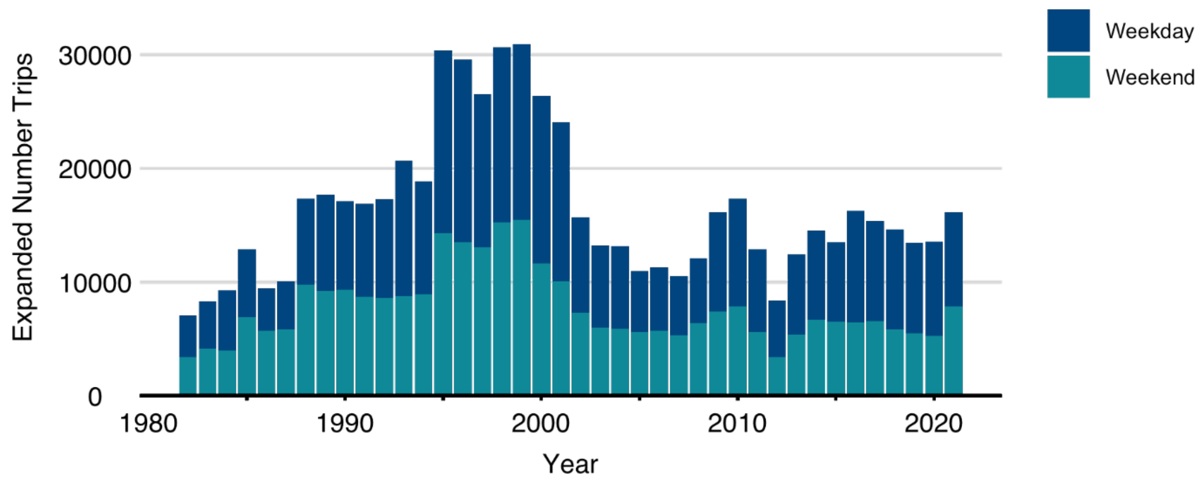


Figure 2-18. Estimated trips per year (all gear types) by type of day.

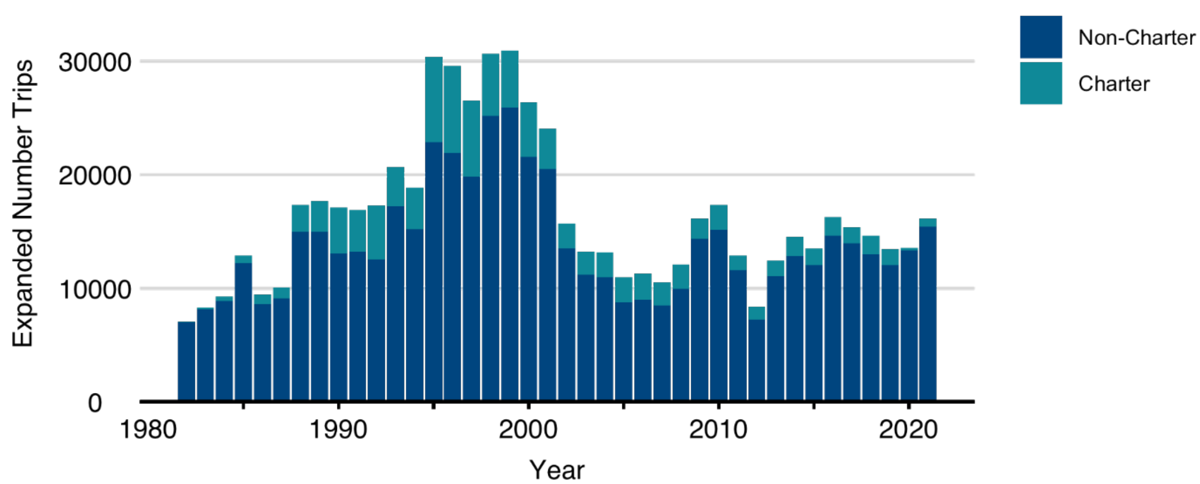


Figure 2-19. Estimated trips per year (all gear types) by charter status.

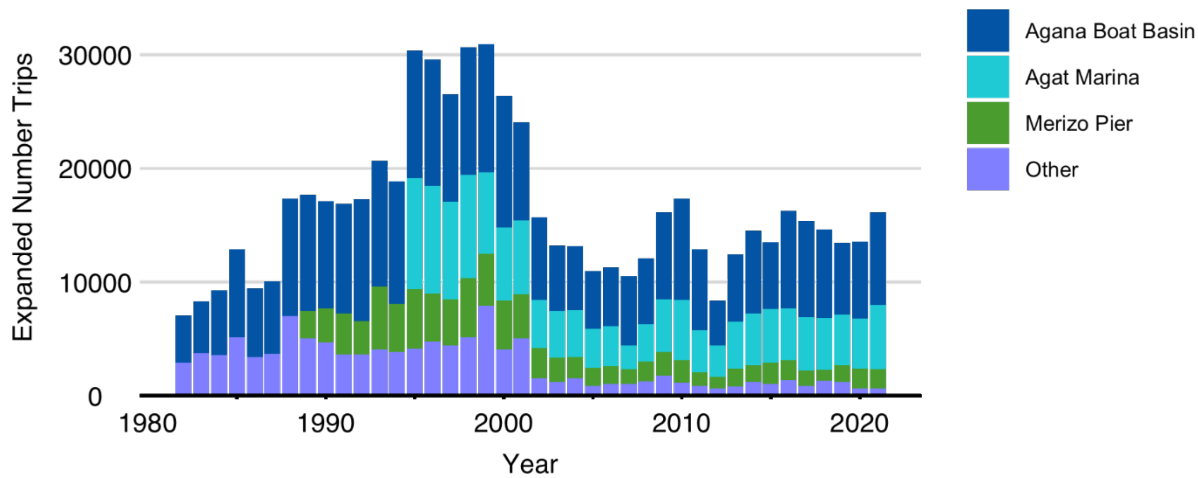


Figure 2-20. Estimated trips per year (all gear types) by port.

2.3 Estimated annual catch

Annual catches (equal to landings, in kg) for all species and species groups listed in the BBS (Table 2-2) were estimated together with a measure of relative error following the expansion methodology described in Ma et al. (2022). Briefly, total catch rates (catch per trip, summed over all species and groups, as kg landed per trip) were estimated for each of the expansion domains (port, gear type, day type, and charter status). The total number of fishing trips for each expansion domain was estimated from participation counts (Section 2.2) then multiplied by catch rates within each expansion domain and summed across domains to give the estimated annual total catch of all species and groups combined. Species- and group-level catch were computed by allocating the total catch across all species according to the relative species and group composition in interviews.

Estimated annual catch of nine groups that likely included BMUS has been relatively small in recent years, but accounted for over 16,000 kg of catch in 1984 (Figures 2-21–2-24). The group with the greatest estimated catch over the timeseries was shallow bottomfish with an average of 1,318 kg/year. Four other groups had an average annual catch of at least 100 kg/year: assorted bottomfish (368 kg/year), Lethrinidae (204 kg/year), deep bottomfish (170 kg/year), and Carangidae (101 kg/year). As with BMUS estimated annual catch, estimated catch of species groups was highly variable over time. For example, Lutjanidae has only been recorded in 13 of the last 40 years, but had estimated annual catch as high as 373 kg during that time.

The annual catch of each of these nine groups was allocated into presumptive component species by assuming that species composition of unidentified (group-level) catch was the same as the species composition of identified (species-level) catch within the BBS interviews for each gear type. Component species for each of the nine groups were defined generally by family and more specifically by species depth preference or fishery targeting behavior (Table 2-2). For instance, all identified species in the family Lutjanidae were classified as potential members of both the ‘assorted bottomfish’ and ‘Lutjanidae’ groups. Twelve species, including 8 BMUS, have listed maximum depths greater than 300 m (Froese and Pauly, 2022) and were considered members of the ‘deep snappers’ and ‘deep bottomfish’ groups. All other species of family Lutjanidae, including *L. kasmira*, have listed maximum depths less than 300 m and were considered members of the ‘shallow snappers’ and ‘shallow bottomfish’ groups. As another example, all identified species in the family Serranidae are potential members of the ‘Serranidae’ group, with the exception of basslets, which are not targeted by fishers. Finally, based on accounts by fishers and DAWR biologists, Caranx i’e’ (or i’i’), which are small juvenile jacks caught nearshore in large number by thrownet or hook-and-line, are almost entirely comprised of *C. melampygus* and *C. sexfasciatus* and do not commonly include *C. ignobilis* or *C. lugubris* (Iwane et al., 2023).

Estimated annual BMUS catch was highly variable over the timeseries and among species (Figures 2-25–2-29). *L. rubrioperculatus* had the highest average annual catch over the timeseries at 5,348 kg. Over the most recent 10 years (2012–2021), *E. coruscans* had the highest average annual catch at 3,585 kg. Three other BMUS had average annual catch of at least 1,000 kg over that period: *P. auricilla* (2,247 kg/year), *L. rubrioperculatus* (1,633 kg/year), and *C. ignobilis* (1,041 kg/year). However, since catch estimates are highly variable over years, some of these species have had low catch in most years. For example, an estimated 6,316 kg of *C. ignobilis* was caught in 2013, but otherwise annual catch has been no higher than 1,800 kg and as low as 17 kg since 2012.

The contribution of partitioned group-level catch to the catch of individual BMUS was generally small. Across all BMUS and non-BMUS, only 0.6% of estimated catch is from species groups that may contain BMUS, though such groups do contribute 6.3% of all BMUS catch. Still, there were notable species and year combinations with a significant contribution from partitioned group catch. For example, the second greatest catch of a BMUS in a single year was 16,922 kg of *L. rubrioperculatus* in 1984, of which 46.8% was from partitioned group catch. The contribution of partitioned species group catch has decreased in recent years. Through the first twenty years of the survey (1982–2001), 8.7% of BMUS catch was from partitioned group catch, whereas in the most recent ten years (2012–2021), this contribution was only 2.0%.

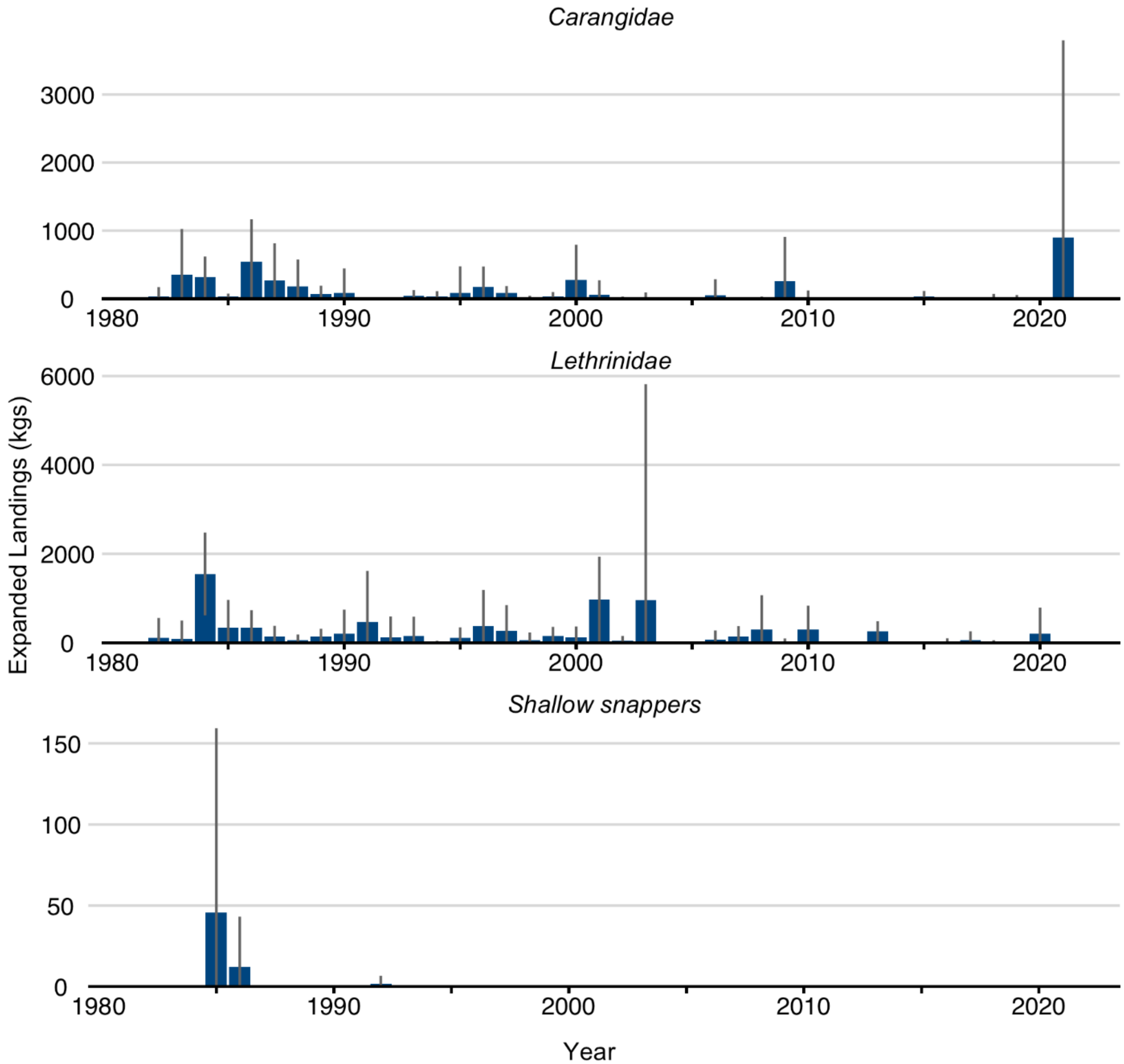


Figure 2-21. Estimated annual catch (landings, kg) of unidentified species groups Carangidae, Lethrinidae, and shallow snappers. Error bars are 95% confidence intervals (± 1.96 standard deviations).

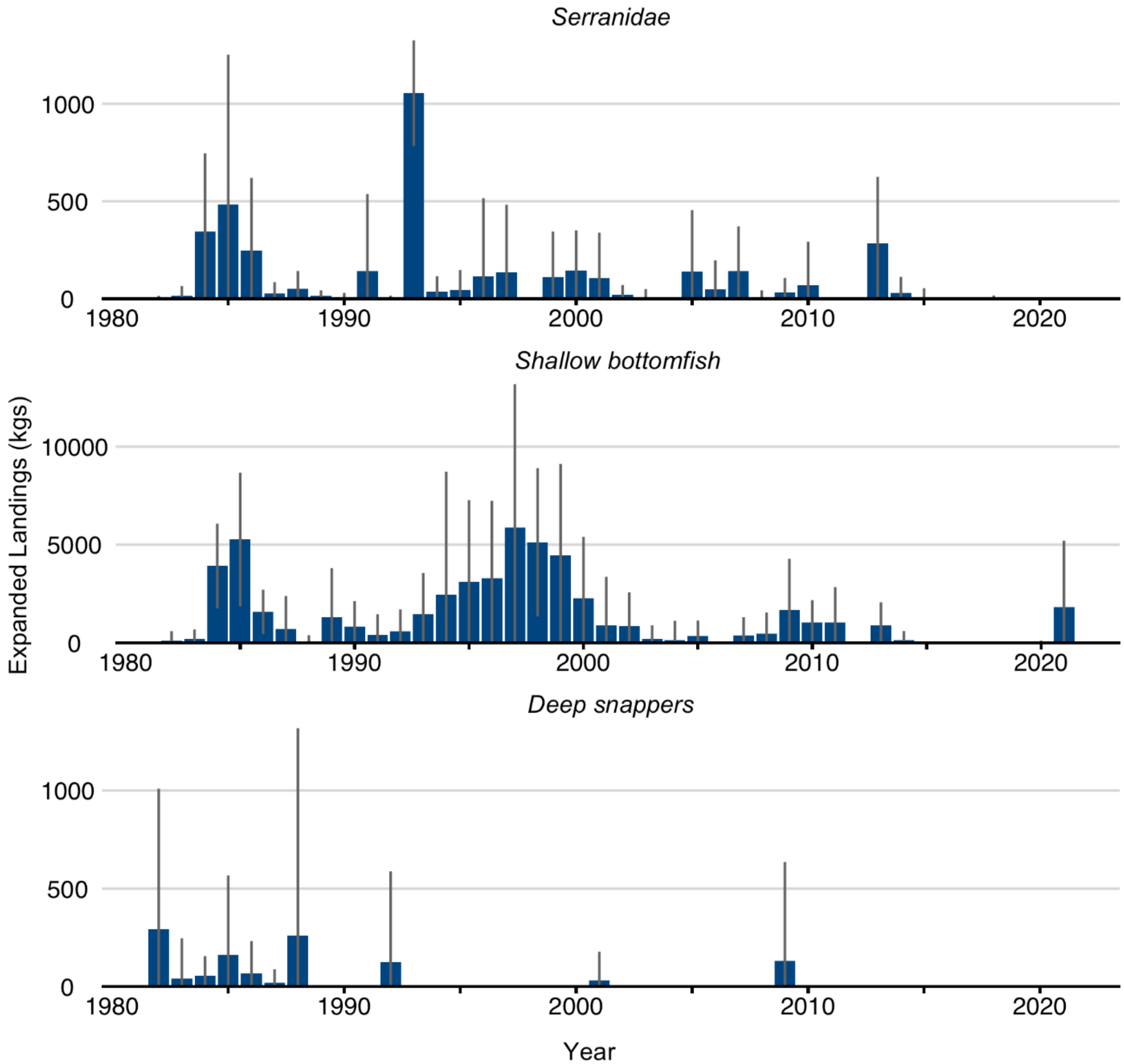


Figure 2-22. Estimated annual catch (landings, kg) of unidentified species groups Serranidae, shallow bottomfish, and deep snappers. Error bars are 95% confidence intervals (± 1.96 standard deviations).

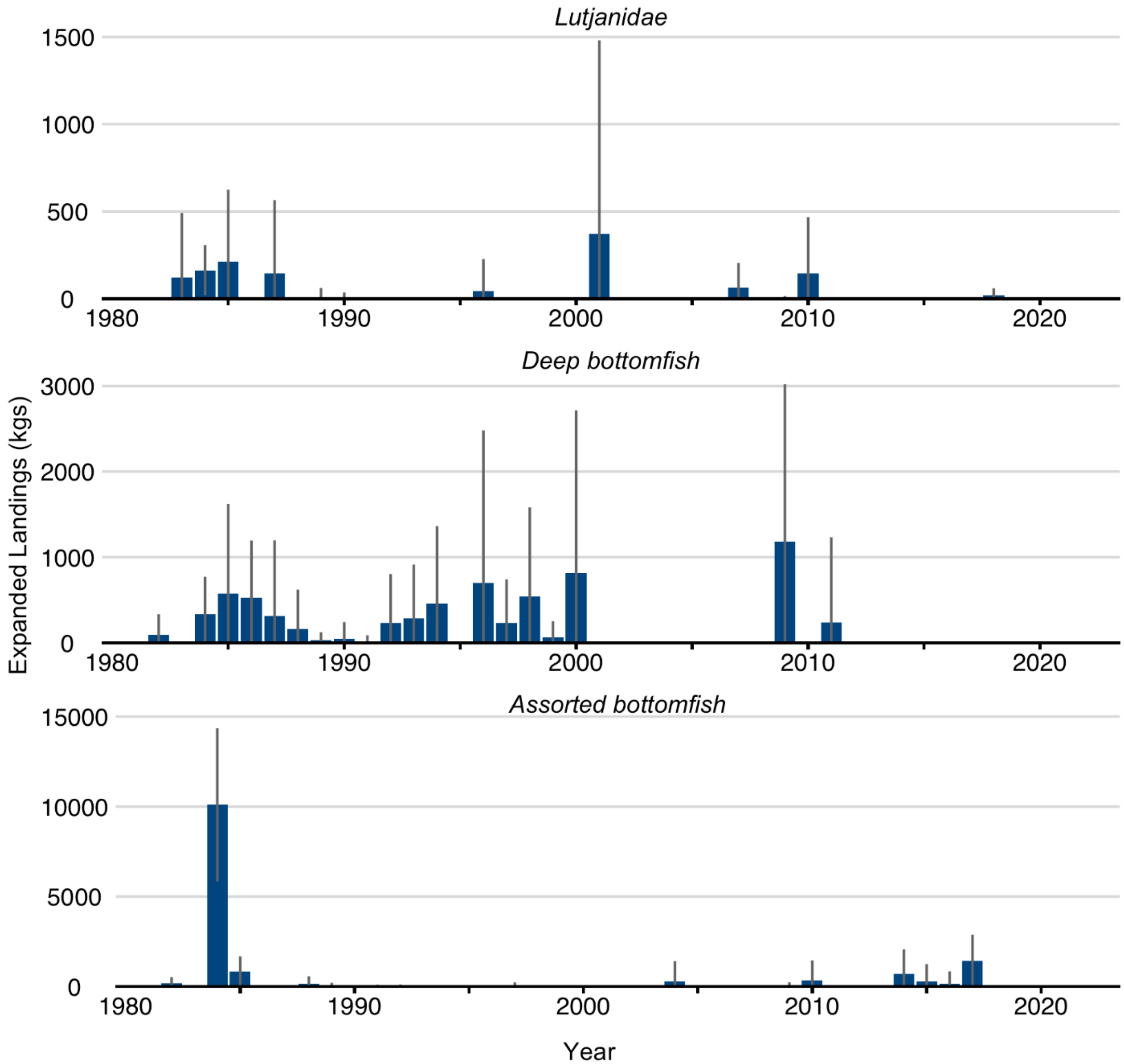


Figure 2-23. Estimated annual catch (landings, kg) of unidentified species groups Lutjanidae, deep bottomfish, and assorted bottomfish. Error bars are 95% confidence intervals (± 1.96 standard deviations).

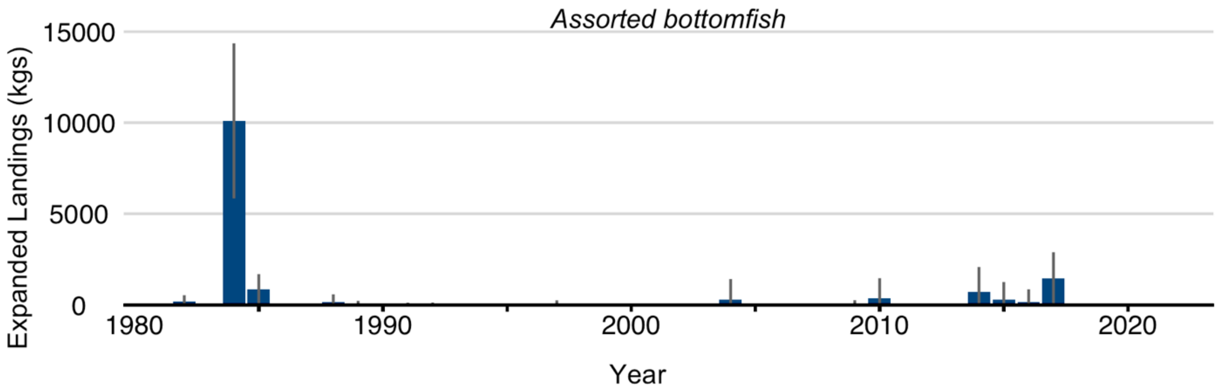


Figure 2-24. Estimated annual landings (catch, kg) of unidentified species group assorted bottomfish. Error bars are 95% confidence intervals (± 1.96 standard deviations).

Table 2-2. A description of presumptive component fish species and groups, listed by family, within the nine groups that could contain BMUS.

Family	Species	Parent Groups
Berycidae	*Beryx decadactylus*	Assorted bottomfish, deep bottomfish
Bramidae	*Eumegistus illustris, Tarachtichthys steindachneri*	Assorted bottomfish, deep bottomfish
	Brama myersi	Assorted bottomfish, shallow bottomfish
Carangidae	*Decapterus spp., Selar crumenophthalmus*	Not included in any group
	Caranx lugubris, Naucrates ductor, Seriola dumerili, Uraspis helvola	Carangidae, assorted bottomfish, deep bottomfish
	C. melampygus, *C. sexfasciatus*	Carangidae, juvenile *Caranx* (Caranx i'e'), assorted bottomfish, shallow bottomfish
	All other species in family Carangidae, including *C. ignobilis* (*N* = 20)	Carangidae, assorted bottomfish, shallow bottomfish
Gempylidae	*Gempylus serpens*	Not included in any group
	Prometheichthys prometheus, Ruvettus pretiosus, Thyrisitoides marleyi	Assorted bottomfish, deep bottomfish
Lethrinidae	*Wattsia mossambica*	Lethrinidae, assorted bottomfish, deep bottomfish
	All other species of Lethrinidae, including *Lethrinus rubrioperculatus* (*N* = 23)	Lethrinidae, assorted bottomfish, shallow bottomfish
Lutjanidae	*Aphareus rutilans, Etelis carbunculus, E. coruscans, E. marshi*, E. radiosus, Pristipomoides argyrogrammicus, P. auricilla, P. filamentosus, P. flavipinnis, P. sieboldii, P. zonatus, Randallichthys filamentosus*	Lutjanidae, deep snappers, assorted bottomfish, deep bottomfish
	All other species of Lutjanidae, including *L. kasmira* (*N* = 23)	Lutjanidae, shallow snappers, assorted bottomfish, shallow bottomfish
Priacanthidae	*Heteropriacanthus cruentatus*	Assorted bottomfish, deep bottomfish
Priacanthidae	All other species of Priacanthidae (*N* = 3)	Assorted bottomfish, shallow bottomfish
Scorpaenidae	*Pontinus macrocephalus, Pontinus sp.,* unidentified Scorpaenidae	Assorted bottomfish, shallow bottomfish
	All other species of Scorpaenidae (*N* = 9)	Not included in any group
Serranidae	*Holanthias borbonius, H. katayamai, Liopropoma maculatum, Plectranthias kamii*	Not included in any group
	Cephalopholis analis, Epinephelus octofasciatus, E. tauvina, Saloptia powelli, Variola louti	Serranidae, assorted bottomfish, deep bottomfish

Family	Species	Parent Groups
	All other species of Serranidae (*N* = 31)	Serranidae, assorted bottomfish, shallow bottomfish

*Invalid synonym of *E. carbunculus*.

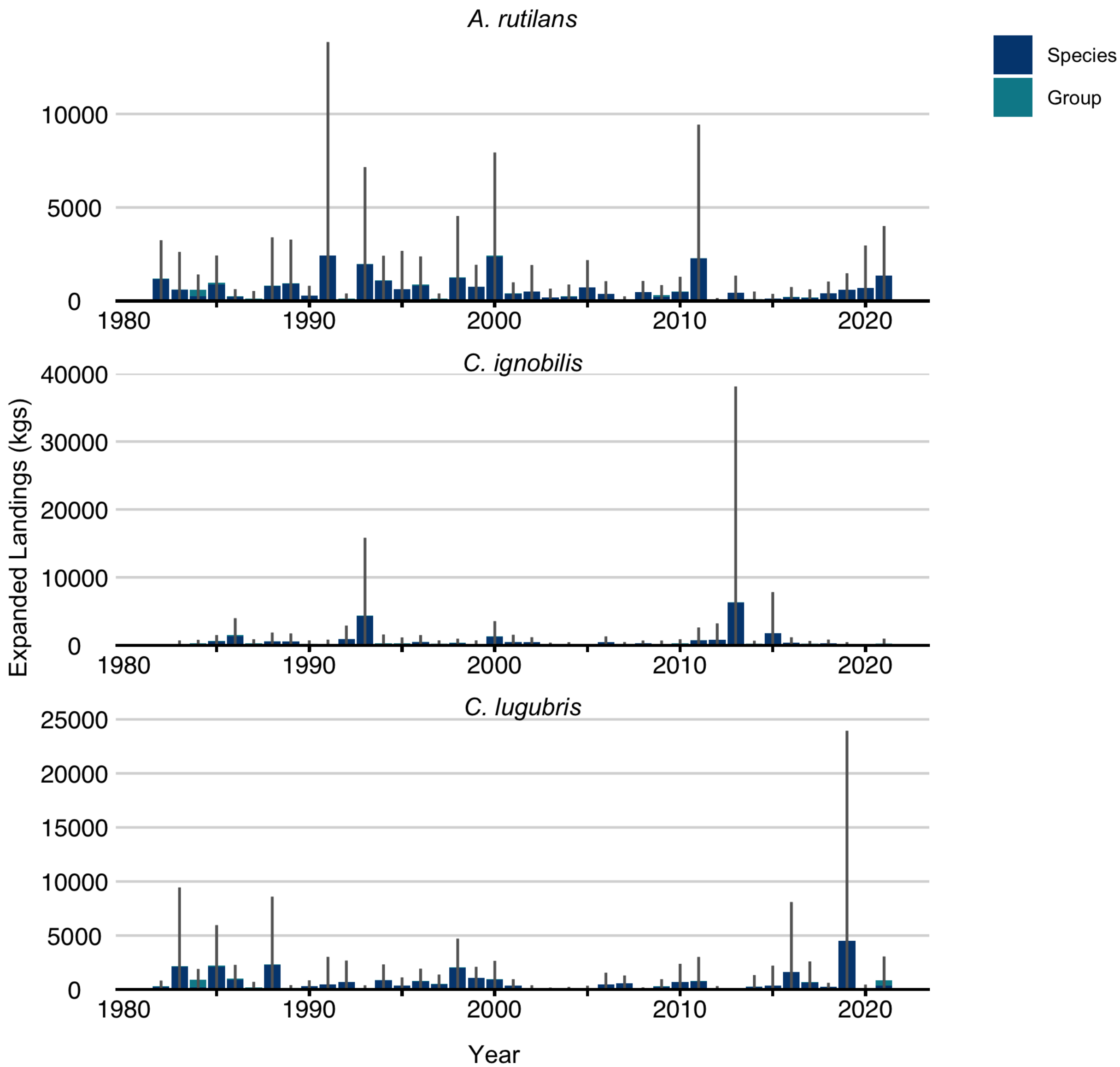


Figure 2-25. Estimated annual catch (landings, kg) of *A. rutilans*, *C. ignobilis*, and *C. lugubris* from directly identified catch and partitioned group-level catch. Error bars are 95% confidence intervals (± 1.96 standard deviations).

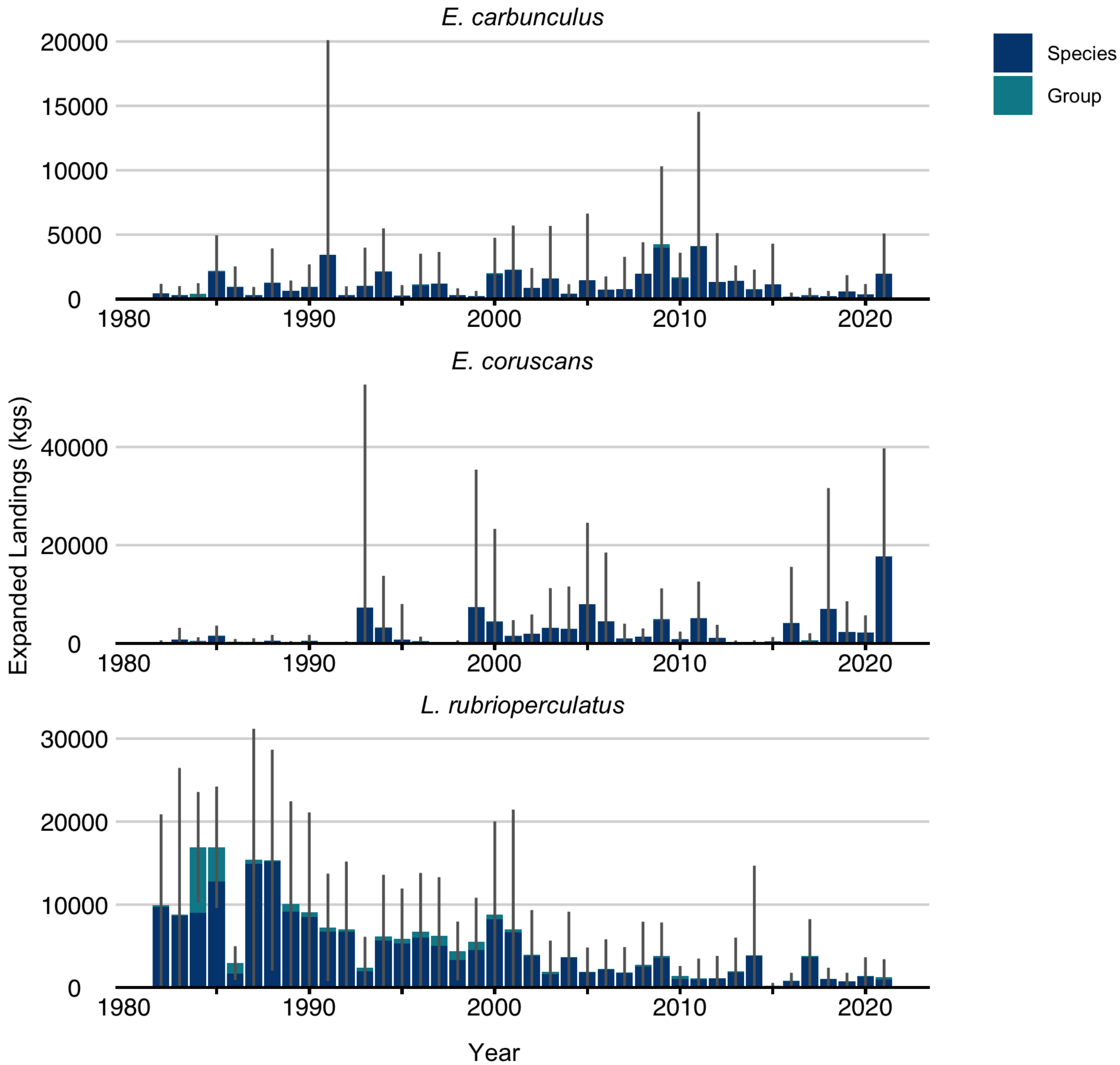


Figure 2-26. Estimated annual catch (landings, kg) of *E. carbunculus*, *E. coruscans*, and *L. rubrioperculatus* from directly identified catch and partitioned group-level catch. Error bars are 95% confidence intervals (± 1.96 standard deviations).

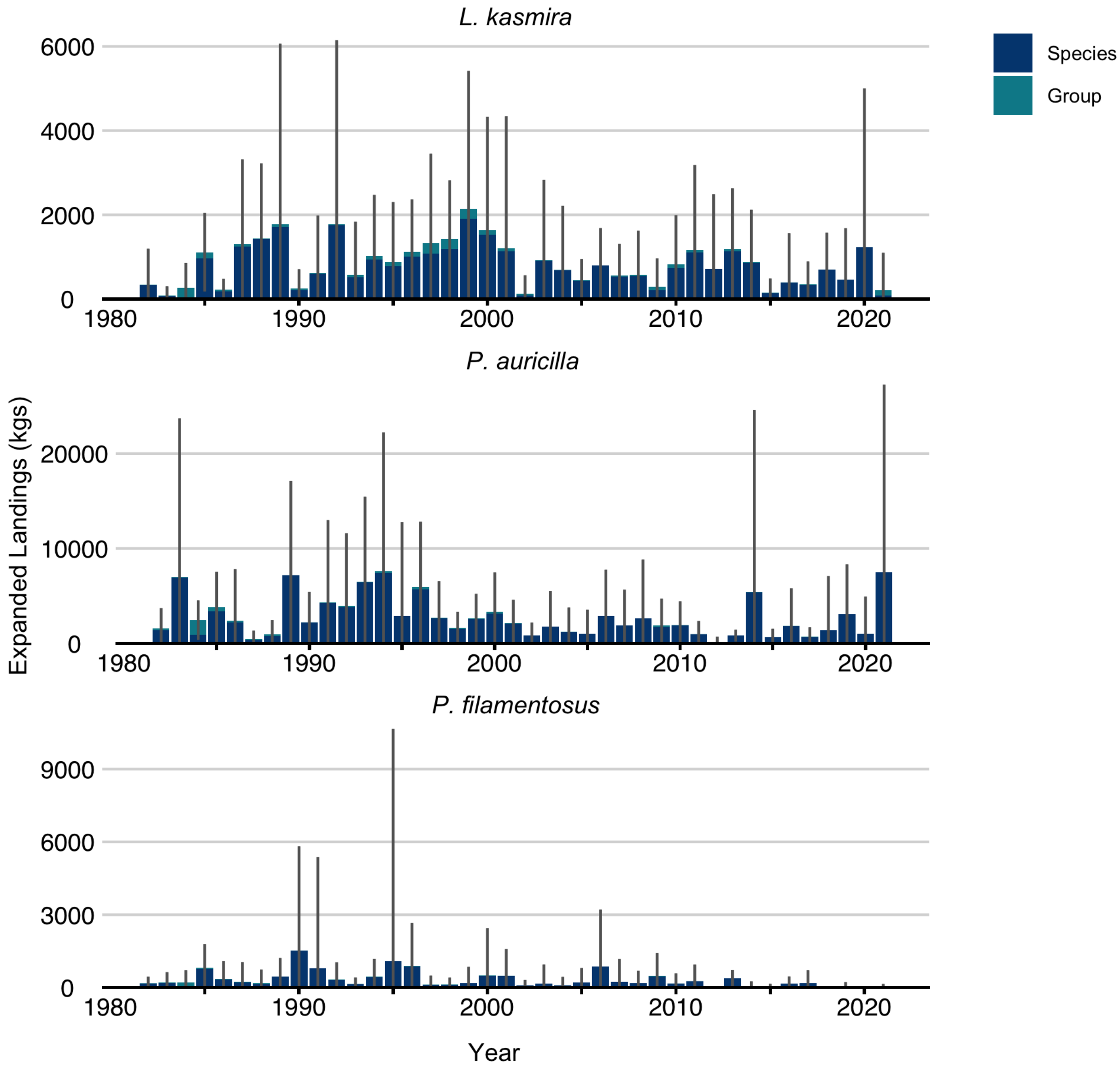


Figure 2-27. Estimated annual catch (landings, kg) of *L. kasmira*, *P. auricilla*, and *P. filamentosus* from directly identified catch and partitioned group-level catch. Error bars are 95% confidence intervals (± 1.96 standard deviations).

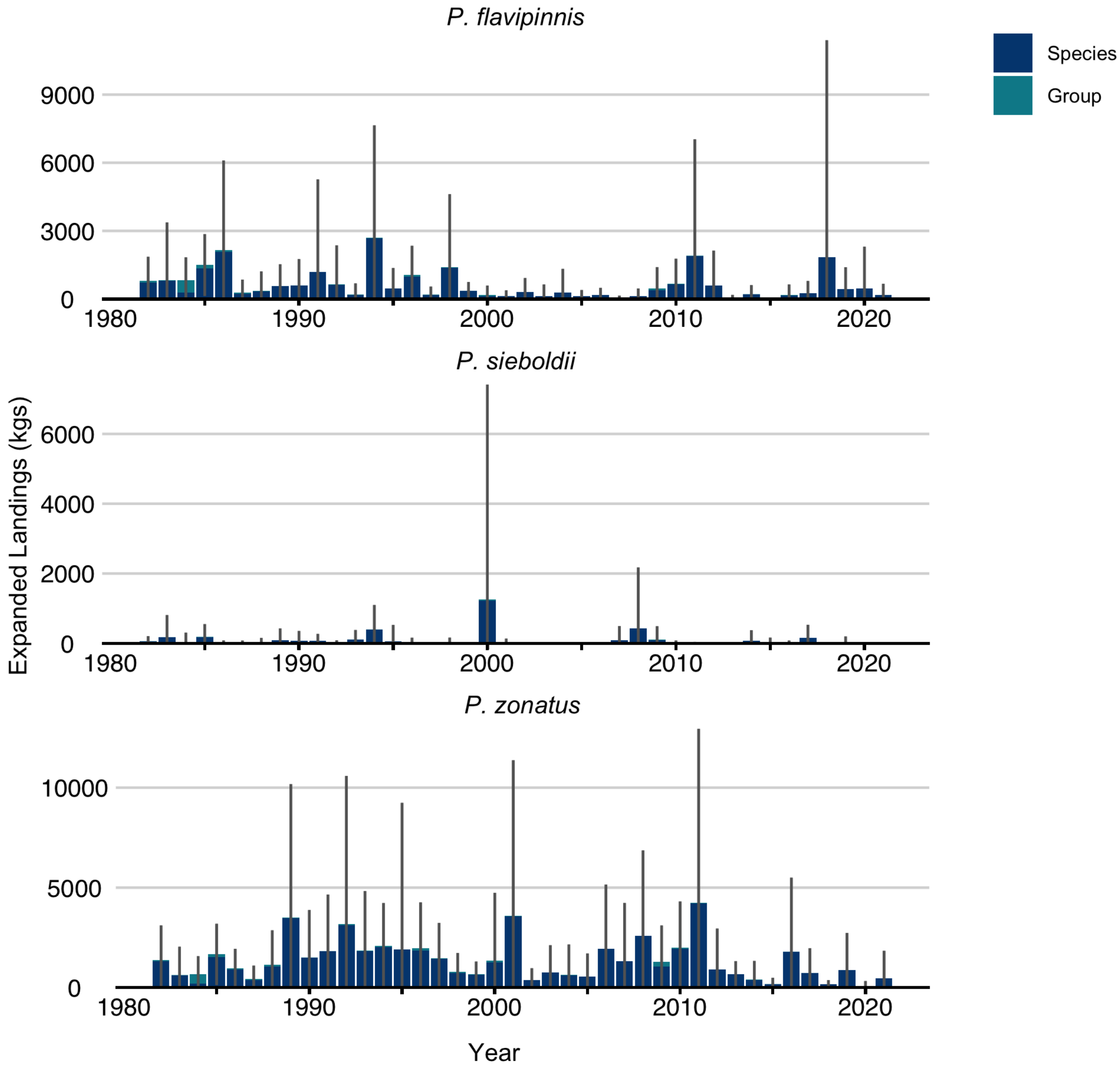


Figure 2-28. Estimated annual catch (landings, kg) of *P. flavipinnis*, *P. sieboldii*, and *P. zonatus* from directly identified catch and partitioned group-level catch. Error bars are 95% confidence intervals (± 1.96 standard deviations).

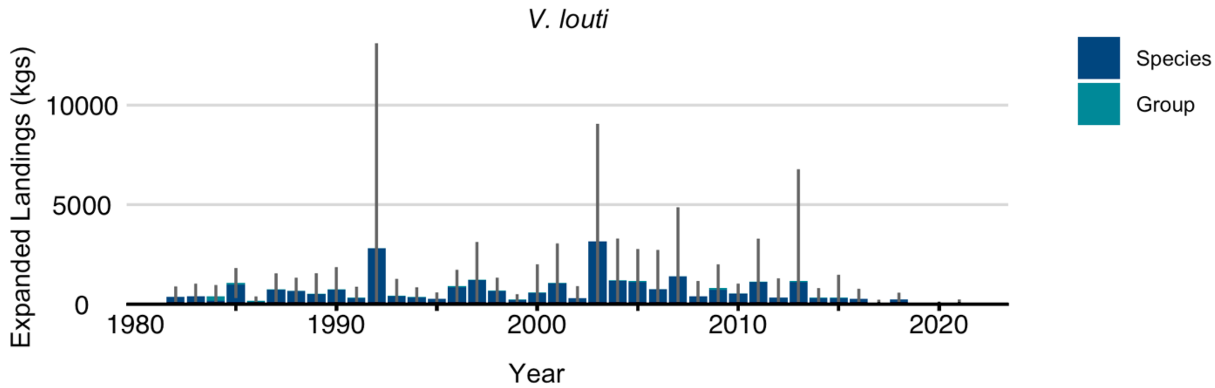


Figure 2-29. Estimated annual catch (landings, kg) of *V. louti* from directly identified catch and partitioned group-level catch. Error bars are 95% confidence intervals (± 1.96 standard deviations).

3. Shore-Based Creel Survey

The Guam Department of Agriculture, Division of Aquatic and Wildlife Resources (DAWR) began conducting a nearshore/inshore creel survey in the early 1970s to monitor fisheries catch and effort along Guam's coast, including nearshore reefs, beaches, and islets (Hamm and Quach, 1988). The survey methodology was modified several times over the years and was largely standardized by October 1984 when it was updated to include nighttime hours. This nearshore/inshore creel survey is now referred to as the Shore-Based Creel Survey (SBS). Detailed methodology of the SBS, including survey design, field data sheets, and specific guidance for field survey technicians, is documented in Jasper et al. (2016).

Briefly, the SBS is composed of two primary data streams: (1) participation estimates (number of fishers and types of fishing) made by survey technicians from the shore and supplemented by aerial surveys to include coastline that is not observable by the technicians, and (2) interviews of fishers intercepted by survey technicians on the shore together with the survey of their catch. The land-based participation survey is performed on four randomly selected days per month: two weekdays and two weekend/holidays. Twice during each survey day (once during the morning shift, beginning at 0630 and once during the evening shift, beginning at 1900), technicians travel along a predetermined coastal route (Figure 3-1) and record the number of fishers, the fishing methods/gears they are using, and location relative to the reef. Observations of fishing activity from a small airplane flying over the coast are sometimes conducted concurrently with the morning shift of the land-based participation surveys to account for fishing activity that is not visible from the coastal survey route (Ma et al., 2022). Interviews are conducted on 4 randomly selected days per month, divided equally between weekdays and weekend/holidays. Interviews are conducted along one survey route during two shifts each day: morning (0630–1200) and evening (1900–2400). The route on the south/southeastern coast of Guam from Merizo to Pago Bay is surveyed a total of two days per month (one weekday and one weekend/holiday), whereas the other two routes are each surveyed one day per month (alternating weekday and weekend/holiday each month).

Although the SBS primarily encounters reef-associated fish and invertebrates, it is included for completeness in this summary of available data for the Guam bottomfish management unit species (BMUS) assessments because some species, particularly juveniles, may be captured by shore-based fishers.

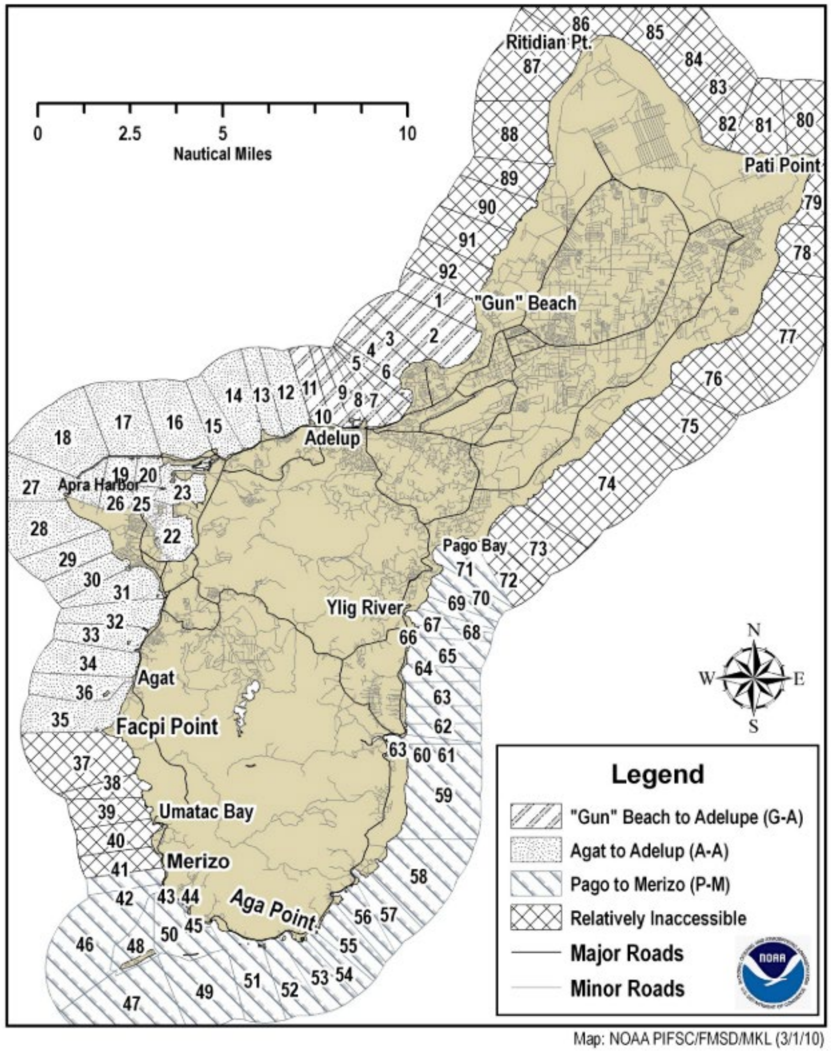


Figure 3-1. Shore-Based Survey map.

3.1 Creel interviews

Participation in SBS interviews is voluntary. Interviewers collect information on effort (hours fished, number and types of fishing gear, and number of fishers), areas fished, environmental conditions (weather, surf height, and tide phase), economic information (% of catch sold and identity of the buyer), bycatch (species, number, condition, and sizes/weights of fish that were thrown back), and catch. Catch information includes total catch per species in numbers and weight and may also include individual fish length or weight observations.

3.1.1 Spatial-temporal and fishing gear effort trends

Over 16,500 interviews were conducted in the Guam SBS from 1984–2021. There were an average of 445 BBS interviews per year from 1985–2021, ranging from 204 interviews in 2020, when both fishing and survey activity were reduced during the COVID-19 pandemic, to 940 interviews in 1999 (Figure 3-2). The spatial distribution of interviews along the 3 survey routes was fairly consistent throughout the timeseries. The northern / northeastern shore of Guam is largely inaccessible due to restricted entry to Anderson Air Force Base and the absence of roads close to the coast but has been periodically surveyed; in 2007, 119 interviews were conducted. The most common gear type in the SBS is hook and line fishing, which accounted for 64% of total interviews from 1984–2021 (Figure 3-3). Interviews of spearfishing are less common owing to limited opportunity for interviewers to intercept fishers during the relatively short time they may be present at the shoreline (Jasper et al., 2016). Spearfishing on SCUBA is rarely interviewed and accounts for less than 1% (*N* = 57) of total interviews. The relative representation of gear types among interviews has been fairly consistent throughout the timeseries, with the more rare gear types appearing slightly more common when the greatest number of interviews was conducted from 1990–2005.

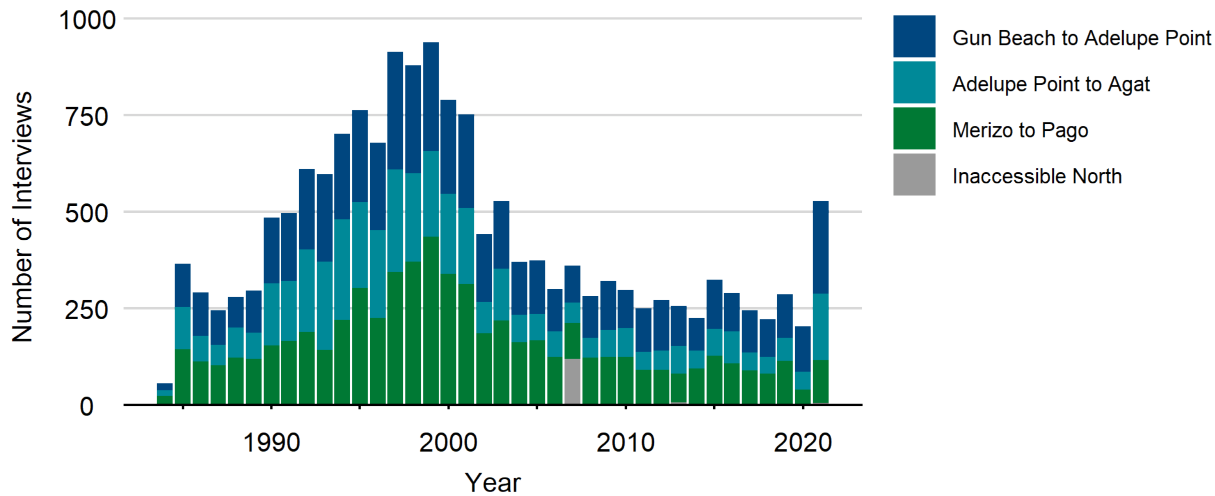


Figure 3-2. Total number of SBS interviews per year by survey route.

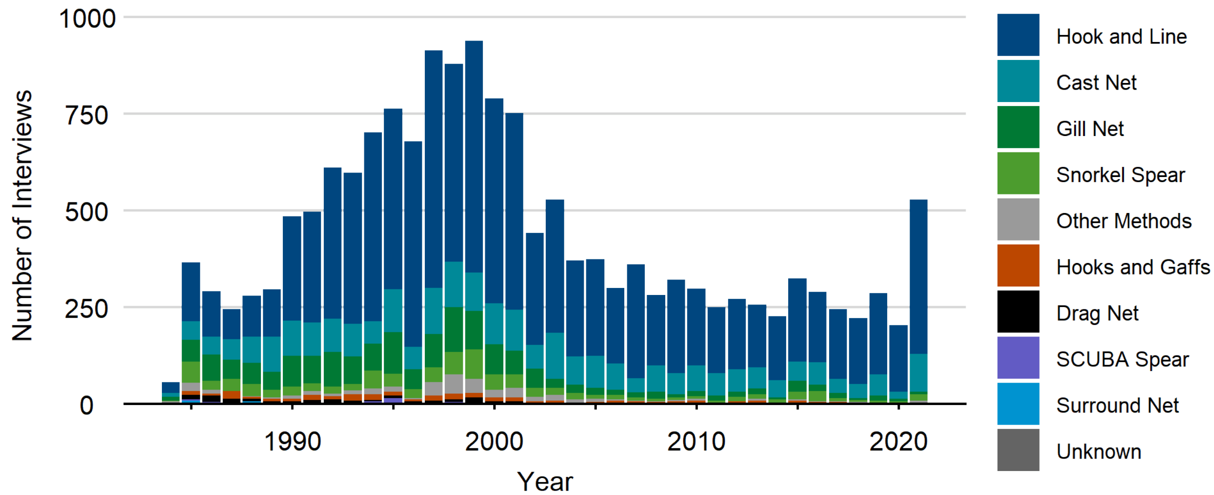


Figure 3-3. Total number of SBS interviews per year by fishing gear.

3.1.2 Species observed

There were 569 species and species groups of fish and invertebrates identified within the SBS survey from 1984–2021, with 132 species and species groups comprising 95% of total recorded catch by weight. The most commonly recorded species by weight included unicornfishes, juvenile rabbitfishes (manahak ha'tang), goatfishes, *S. crumenophthalmus* (atulai), juvenile Carangidae (Caranx i'e'), and octopus (Table 3-1).

Table 3-1. Surveyed catch by species (as percent total weight) from SBS interviews 1984–2021.

Name	Percent Surveyed (%)
Naso unicornis	7.4
Juvenile rabbitfish	6.7
Mulloidichthys flavolineatus	6.5
Selar crumenophthalmus	6.2
Juvenile *Caranx spp.*	3.7
Acanthurus triostegus	3.6
Unspecified octopus	3.0
Caranx melampygus	2.8
Naso lituratus	2.5
Lethrinus harak	2.3
Gerres acinaces	1.9
Kyphosus cinerascens	1.9
Juvenile goatfish	1.8
Octopus ornatus	1.8
Ellochelon vaigiensis	1.7
Moolgarda engeli	1.6
All other species and groups (*N* = 553)	44.6

3.1.3 BMUS species occurrence

BMUS are rare in the SBS interview data. Six BMUS (*A. rutilans*, *C. ignobilis*, *C. lugubris*, *L. rubrioperculatus*, *L. kasmira*, and *V. louti*) were recorded across 125 total interviews from 1984–2021. *C. ignobilis* was the most frequently encountered BMUS (*N* = 64 interviews), whereas *A. rutilans* and *V. louti* were recorded in just 1 interview each. In addition, several species groups which could potentially include BMUS were also recorded in the data, including Carangidae, Lethrinidae, Lutjanidae, and Serranidae. The proportion of total interviews where BMUS were recorded was small for all species and groups (Figure 3-4).

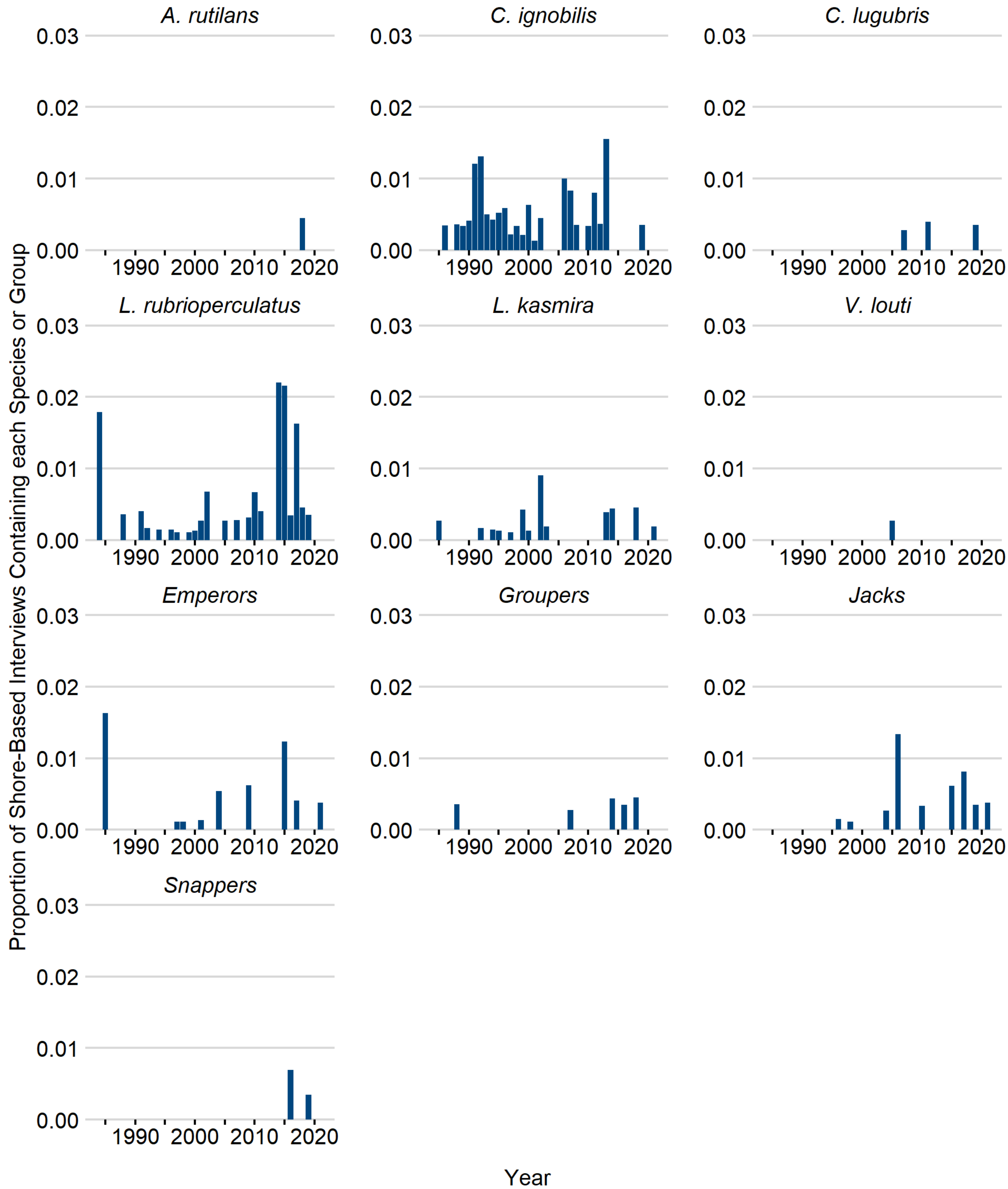


Figure 3-4. Proportion of SBS interviews positive for each BMUS and BMUS group.

3.1.4 Size data

Given the relatively rare occurrence of BMUS within the SBS data, there were few size measurements available for even the most frequently encountered BMUS (Figure 3-5).

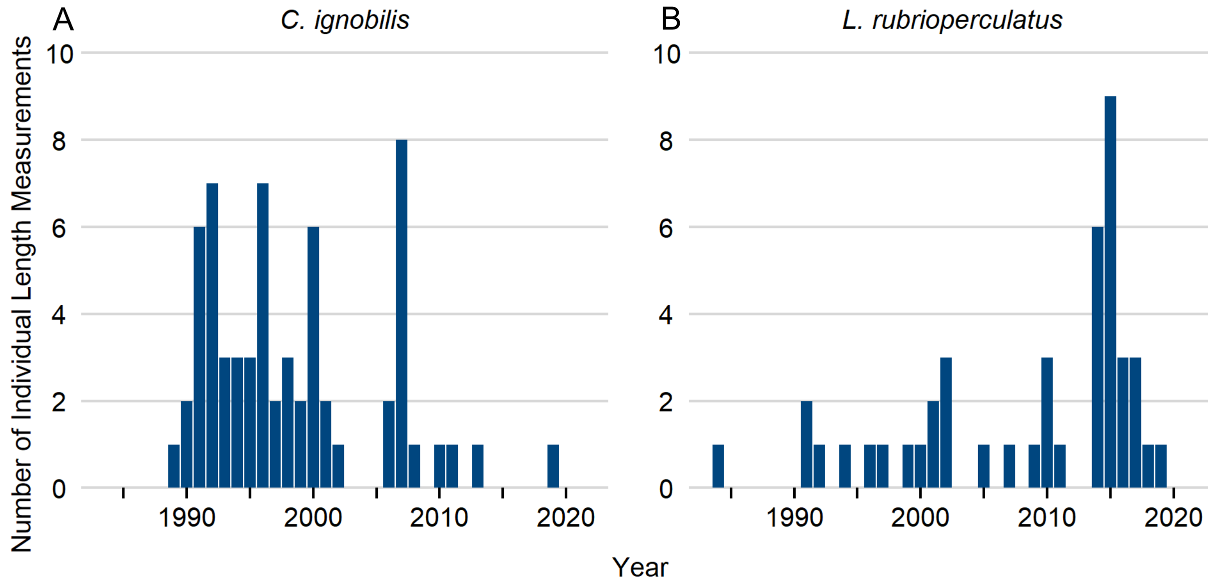


Figure 3-5. The number of individual length measurements per year of (A) *C. ignobilis* and (B) *L. rubrioperculatus* from the SBS interviews where every individual of the species or group was measured.

3.2 Estimated annual catch

As indicated from SBS interviews, only six of the thirteen BMUS (*A. rutilans*, *C. ignobilis*, *C. lugubris*, *L. rubrioperculatus*, *L. kasmira*, and *V. louti*) had non-zero annual catch estimates for any years from 1985–2021 (Figures 3-6 and 3-7). *C. ignobilis* had the highest average annual catch over the timeseries at 171 kg, followed by *L. rubrioperculatus* at 48 kg. No other BMUS had average annual catch greater than 10 kg. Annual catch is highly variable within species. For example, an estimated 1,405 kg of *C. ignobilis* was caught in 1998, but average catch over the most recent 10 years (2012–2021) was only 17 kg/year.

The contribution of partitioned group-level catch to the catch of individual BMUS was minor (less than 2% of annual total) for all BMUS. Of an estimated 3,449 kg of species groups that may contain BMUS from 1985–2021, only 76 kg or 2.2% was partitioned to BMUS.

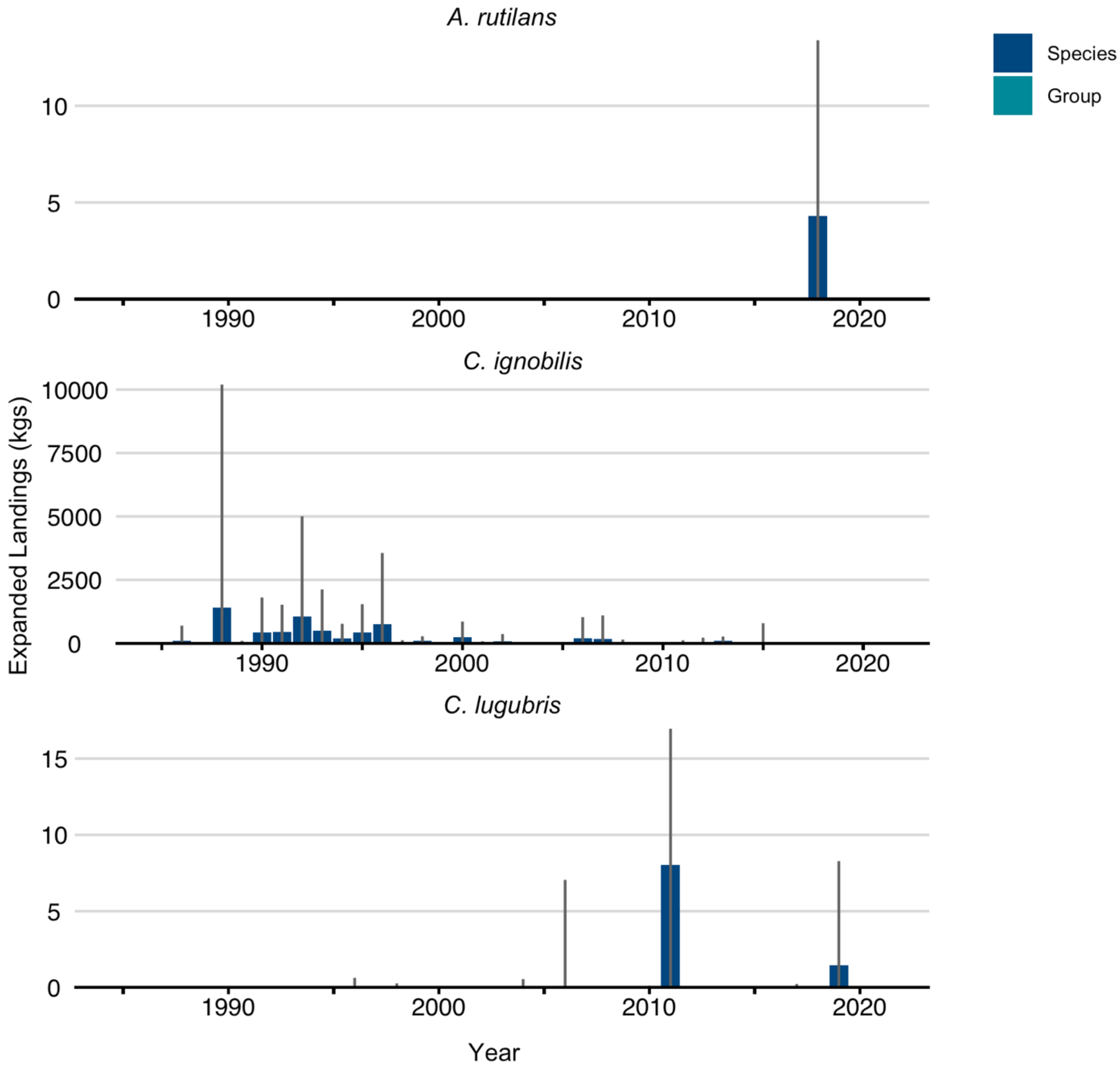


Figure 3-6. Estimated annual catch (landings, kg) of *A. rutilans*, *C. ignobilis*, and *C. lugubris* from directly identified catch and partitioned group-level catch. Error bars are 95% confidence intervals (± 1.96 standard deviations).

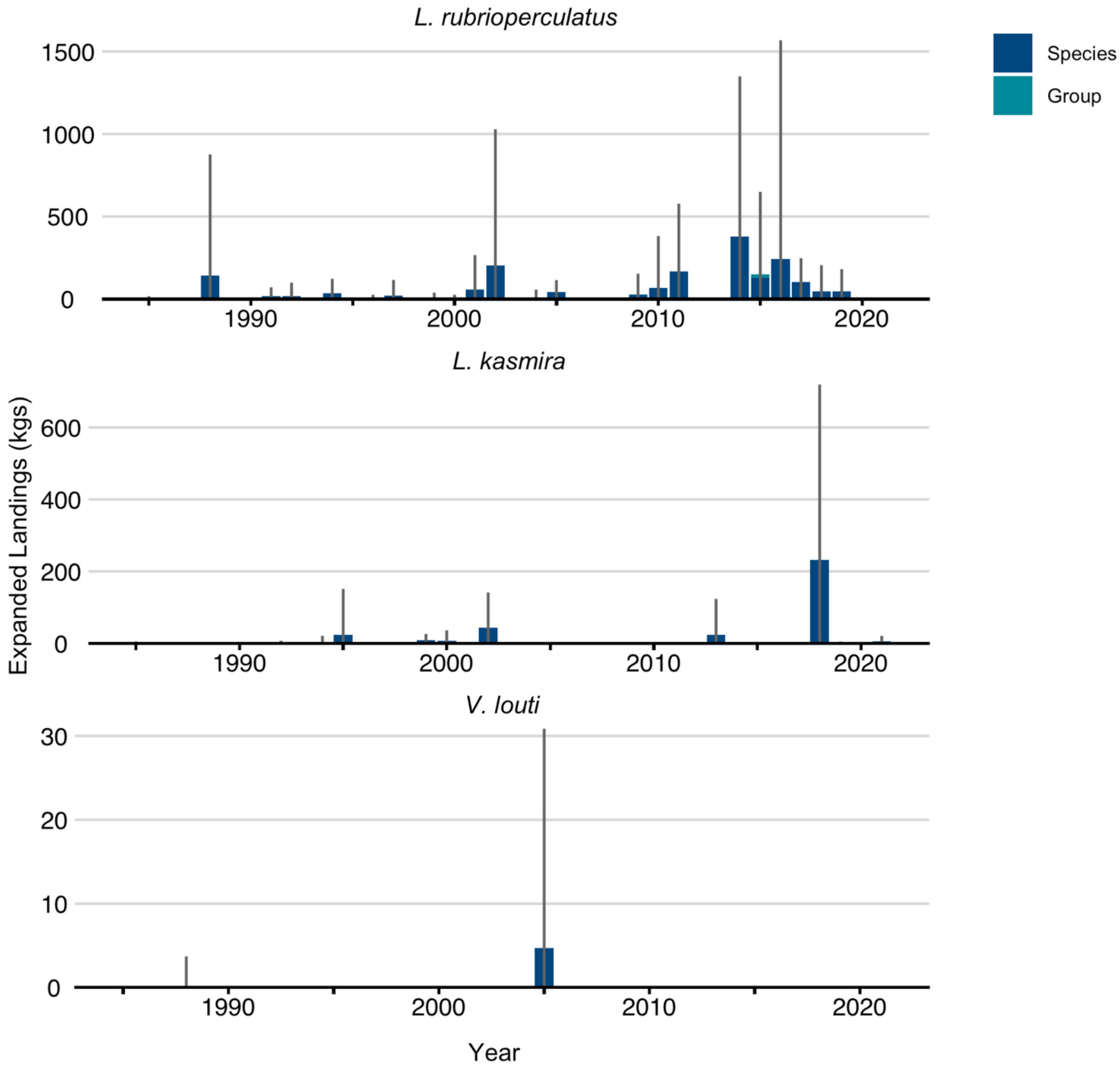


Figure 3-7. Estimated annual catch (landings, kg) of *L. rubrioperculatus*, *L. kasmira*, and *V. louti* from directly identified catch and partitioned group-level catch. Error bars are 95% confidence intervals (± 1.96 standard deviations).

Only four species groups that may contain BMUS were recorded in the SBS, all of which are family-level groups: Carangidae, Lethrinidae, Lutjanidae, and Serranidae (Figures 3-8 and 3-9). Lethrinidae had the greatest average estimated annual catch (56 kg), followed by Carangidae (32 kg). Neither Lutjanidae and Serranidae were recorded often. As with BMUS estimated annual catch, estimated catch of species groups was highly variable over time. For example, despite average estimated annual catch of 32 kg, Carangidae only exceeded that value in 3 of 37 years and was not recorded at all in 28 years.

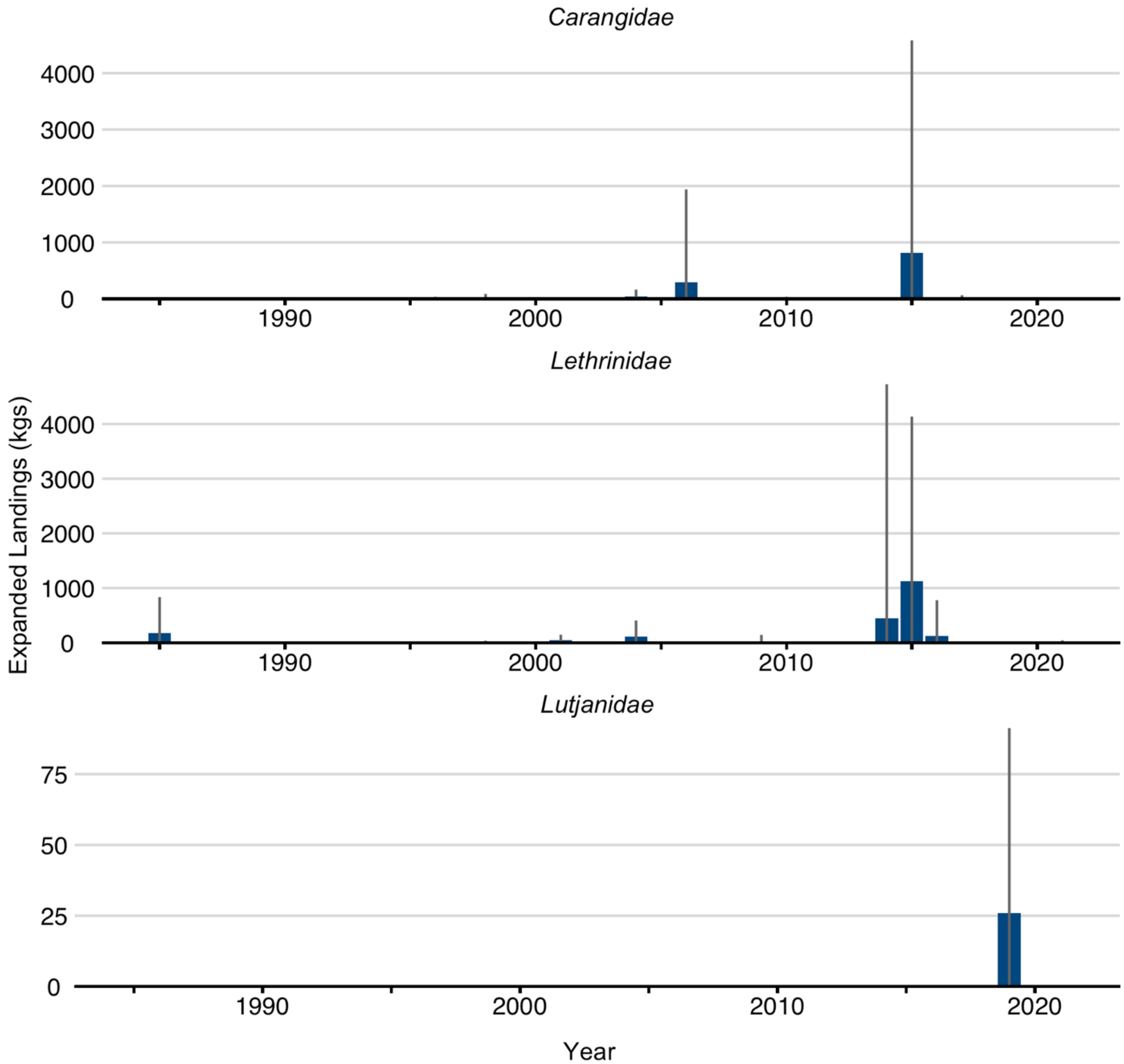


Figure 3-8. Estimated annual catch (landings, kg) of unidentified species groups Carangidae, Lethrinidae, and Lutjanidae. Error bars are 95% confidence intervals (± 1.96 standard deviations).

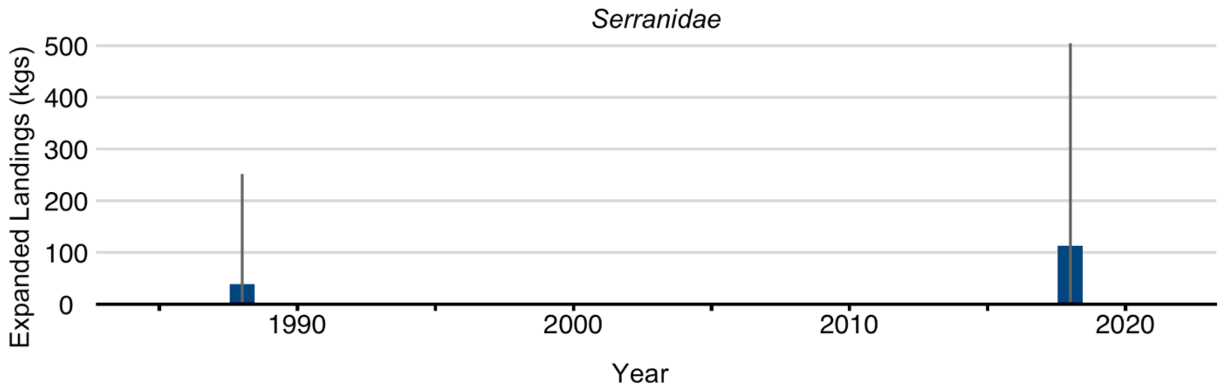


Figure 3-9. Estimated annual catch (landings, kg) of unidentified species group Serranidae. Error bars are 95% confidence intervals (± 1.96 standard deviations).

4. PIFSC Biosampling Program

The National Marine Fisheries Service (NMFS) developed and funded the Commercial Fisheries Biosampling Program in 2009 (Sundberg et al., 2015). The Biosampling Program provided financial support to each of the six NMFS Science Centers to enhance data collection, especially for fish stocks for which there were limited data available. The Pacific Islands Fisheries Science Center (PIFSC) contracted and trained biosampling teams in each of the western Pacific territories, working with the support of their respective marine resource agencies [e.g., Guam Division of Aquatic and Wildlife Resources (DAWR)]. In each region, the biosampling teams implemented standardized sampling techniques outlined by PIFSC.

The primary goal of biosampling teams was to establish cooperative relations with local fish markets, fishers, and vendors to acquire length and weight measurements of as many species and individuals as possible to use for length-weight regressions. These length-weight data could provide species and size composition information to support the development of stock assessments, but would require understanding of any potential selectivity processes affecting the catch that was available to biosampling teams. Some species and size classes were further sampled for otoliths, gonads, and fin clips to support PIFSC research on life history processes including growth, maturity, and longevity (Sundberg et al., 2015). The Western Pacific Fisheries Information Network (WPacFIN) at PIFSC maintains and updates the database for biosampling data. The Fisheries Research and Monitoring Division Life History Program at PIFSC compiles and frequently publishes age-at-length (e.g., parameterized growth functions), maturity-at-length, and additional life history investigations for Western Pacific fish species.

Biosampling teams in Guam began regularly sampling reef and bottomfishes in August 2009 at the Guam Fishermen’s Co-op Association fish market in Hagatna. All biosampling supplies, training, technical support, contracts for local fishers, and external support for processing collected specimens (otoliths, gonads, and fin clips) were provided by PIFSC. All fish lengths (fork length to the nearest 0.1 cm) and body weights (g) were obtained using a 75-cm fish measuring board, 1-m calipers or 150-cm tape measure (when needed for larger fish), and a digital bench scale. Most of the biosampling effort was geared towards documenting species composition and collecting length and weight measurements of the entire catch brought to market by individual fishers comprising the “field” data set in Guam (Sundberg et al., 2015). Technicians recorded details about the fisher (seller), general area fished, fishing start and end date and time, hours fished, fishing methods, and fishing gears. After the entire commercial catch for each fisher was measured, fishes identified as a current priority for life history research were processed for otoliths and tissues, which in some instances necessitated purchasing the individual fish from the fisher. Individuals subsampled and aged for life history research comprised the “lab” data set. Because the lab data set is a non-random subsample of the total catch and varied according to life history research priorities, the age compositions of these fish cannot be used directly in stock assessments. However, the length-weight measurements within the field data set could provide species and size composition information to support the development of stock assessments.

4.1 Size data

Bottomfish management unit species (BMUS) length and weight measurements were collected by Guam biosampling teams for 18,989 individuals from 2009 through 2021. The number of individuals measured varied greatly by species, ranging from 279 *P. filamentosus* to 7,868 *L. rubrioperculatus* (Figure 4-1). The majority of BMUS measurements were from fishing trips that used bottomfishing gear exclusively (63% of total measured BMUS) or trips that reported using both bottomfishing and troll gear (26%). The number of individuals measured of each BMUS was highly variable from year to year. Considering bottomfishing and bottomfishing / troll mix trips combined, 8 of the 13 BMUS (*C. ignobilis*, *A. rutilans*, *V. louti*, *P. filamentosus*, *C. lugubris, P. sieboldii*, *E. coruscans*, and *P. flavipinnis*) had < 50 individuals measured in most years of the timeseries (Figure 4-2). *C. ignobilis* and *V. louti* were more often measured from spearfishing than bottomfishing or bottomfishing / troll mix trips; however, the number of individuals measured per year was generally small and varied over the timeseries (Figure 4-3A–B). Similarly, *C. ignobilis* were most often measured from net gears, but the number of individuals measured was less than 30 in most years (Figure 4-3C).

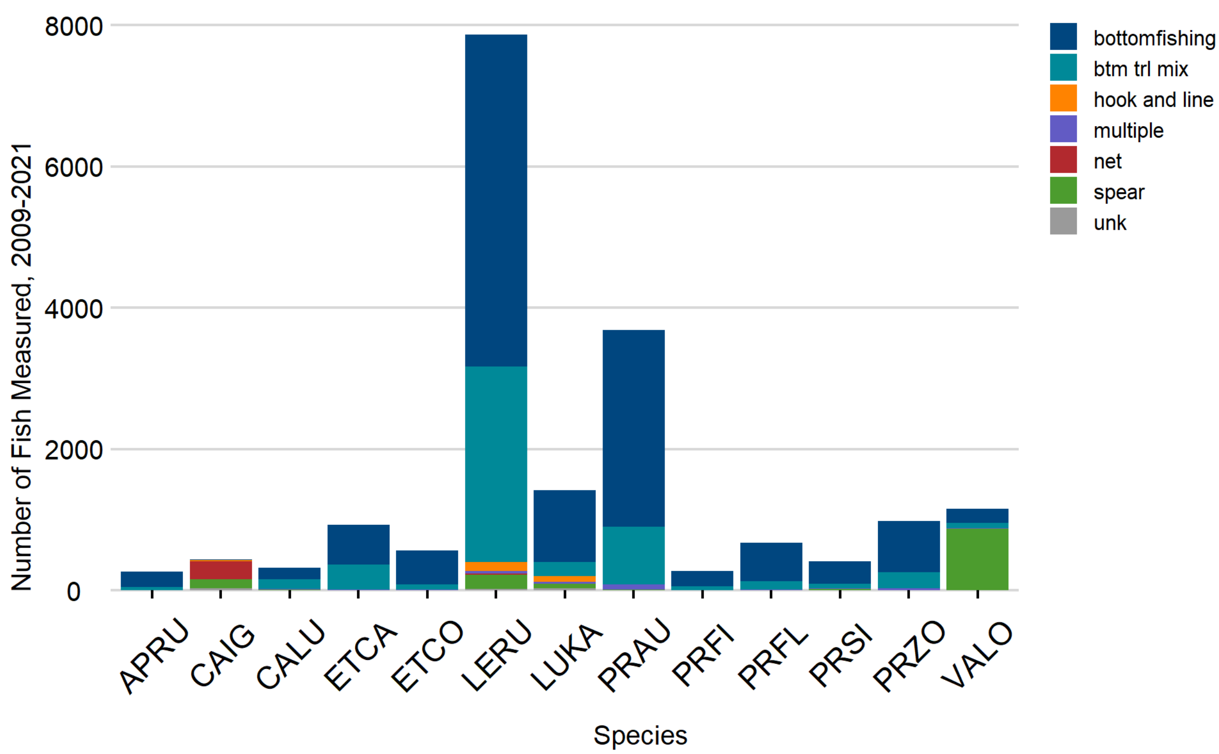


Figure 4-1. Number of fish measured in the biosampling field data set, all years combined, by fishing gear for each BMUS. Species codes are the first two letters of the genus and species name (see Table 1-1).

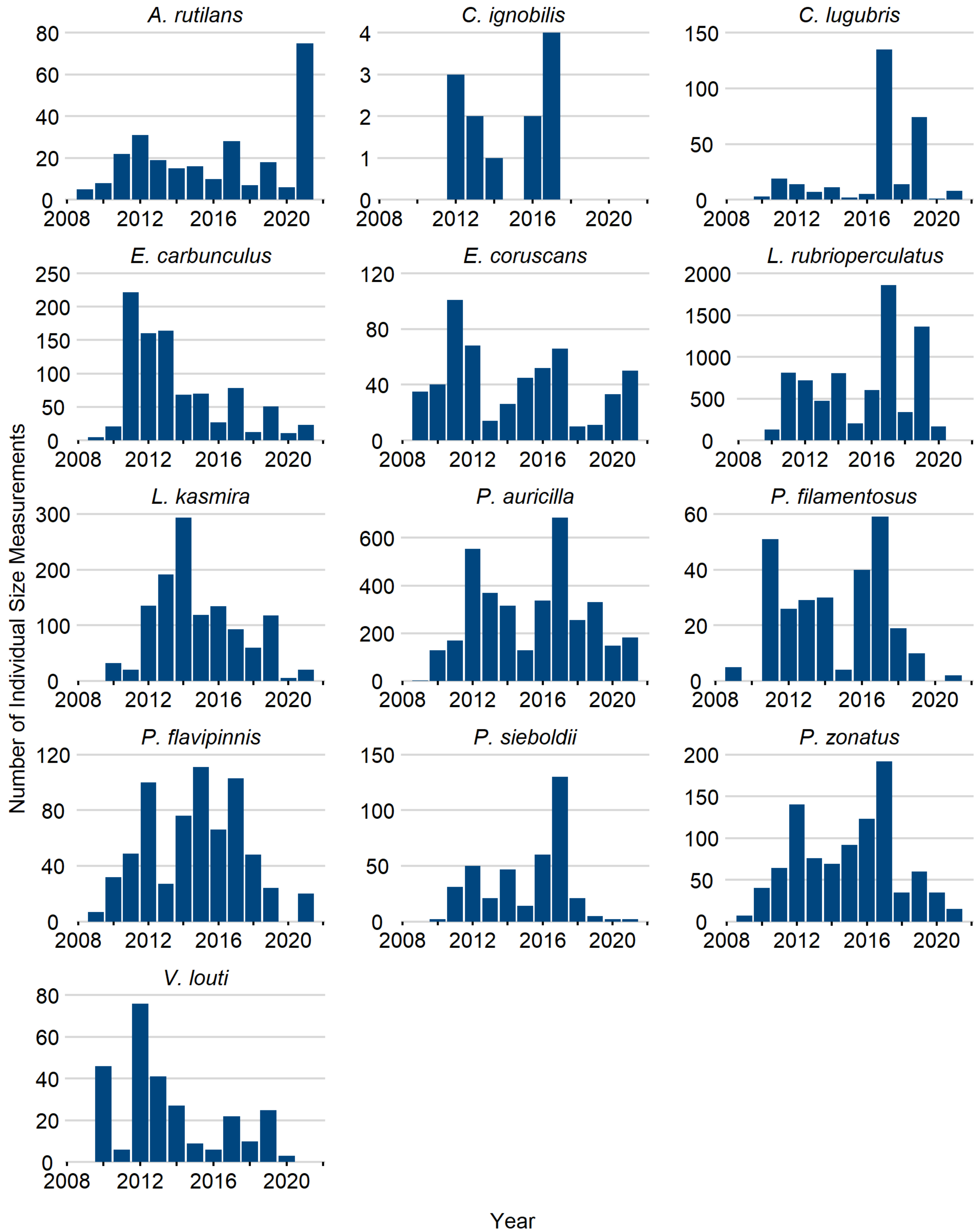


Figure 4-2. Individual BMUS size observations per year by species from the biosampling field data set for bottomfishing and bottomfishing / troll mix trips combined.

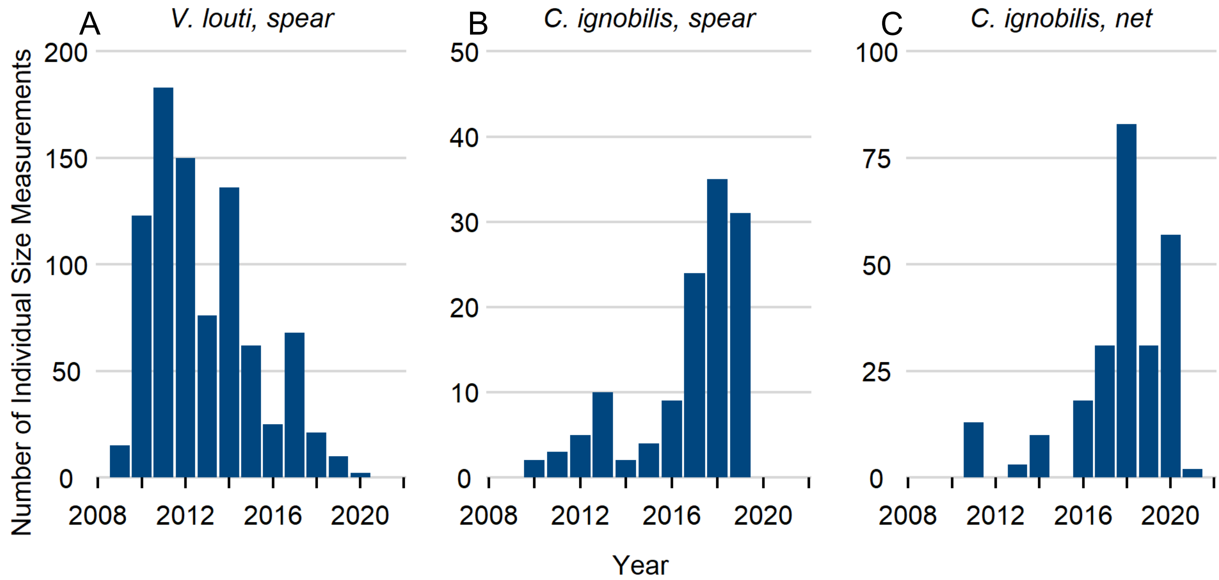


Figure 4-3. The number of individual size observations per year from the biosampling field data set for (A) *V. louti* spearfishing, (B) *C. ignobilis* spearfishing, and (C) *C. ignobilis* net gears (gillnet, talaya/castnet, and unspecified net).

The lengths or weights of individual fish in the biosampling field data can be useful for stock assessment in several ways, including timeseries of annual size compositions for age-structured assessment models, aggregate recent size compositions for size-based data-limited assessment approaches, and size compositions over a specific time period to infer size-based selectivity of fishing fleets. The majority of BMUS had few individuals measured in most years of the timeseries, which generally precludes using biosampling size measurements for annual length compositions within age-structured assessment models. Biosampling size measurements of *P. auricilla*, *L. rubrioperculatus*, *L. kasmira*, and *P. zonatus* are most likely among the BMUS that were sufficiently numerous and consistent over the years to be useful for annual size composition for stock assessment inputs. For example, *P. auricilla* were particularly well-sampled in the biosampling field data set and provide information on changes of individual lengths within the catch from year to year (Figure 4-4).

The number of biosampling size measurements from bottomfishing and bottomfishing / troll mix trips aggregated over the past 5 years (2017–2021) varied among BMUS, ranging from 4 *C. ignobilis* to 3,725 *L. rubrioperculatus*. Whereas recent biosampling size measurements for most BMUS provide a somewhat consistent, unimodal length frequency distribution that could be informative for size-based data-limited assessment approaches or to infer size-based fishing selectivity, length frequency distributions of *A. rutilans* and *P. filamentosus* display an interesting second mode of larger individuals (Figure 4-5). Biosampling teams have collected more *V. louti* measurements from spearfishing gears (*N* = 101 individuals) than bottomfishing and bottomfishing / troll mix trips (*N* = 60 individuals), and spearfishing included somewhat larger individuals (Figure 4-6A). *C. ignobilis*, which were rarely encountered by technicians from bottomfishing and bottomfishing / troll mix trips, were measured most often from net (*N* = 204 individuals) and spearfishing (*N* = 90 individuals) gears, with individuals approximately 20 cm dominating the observed catch from both gear types (Figure 4-6B–C).

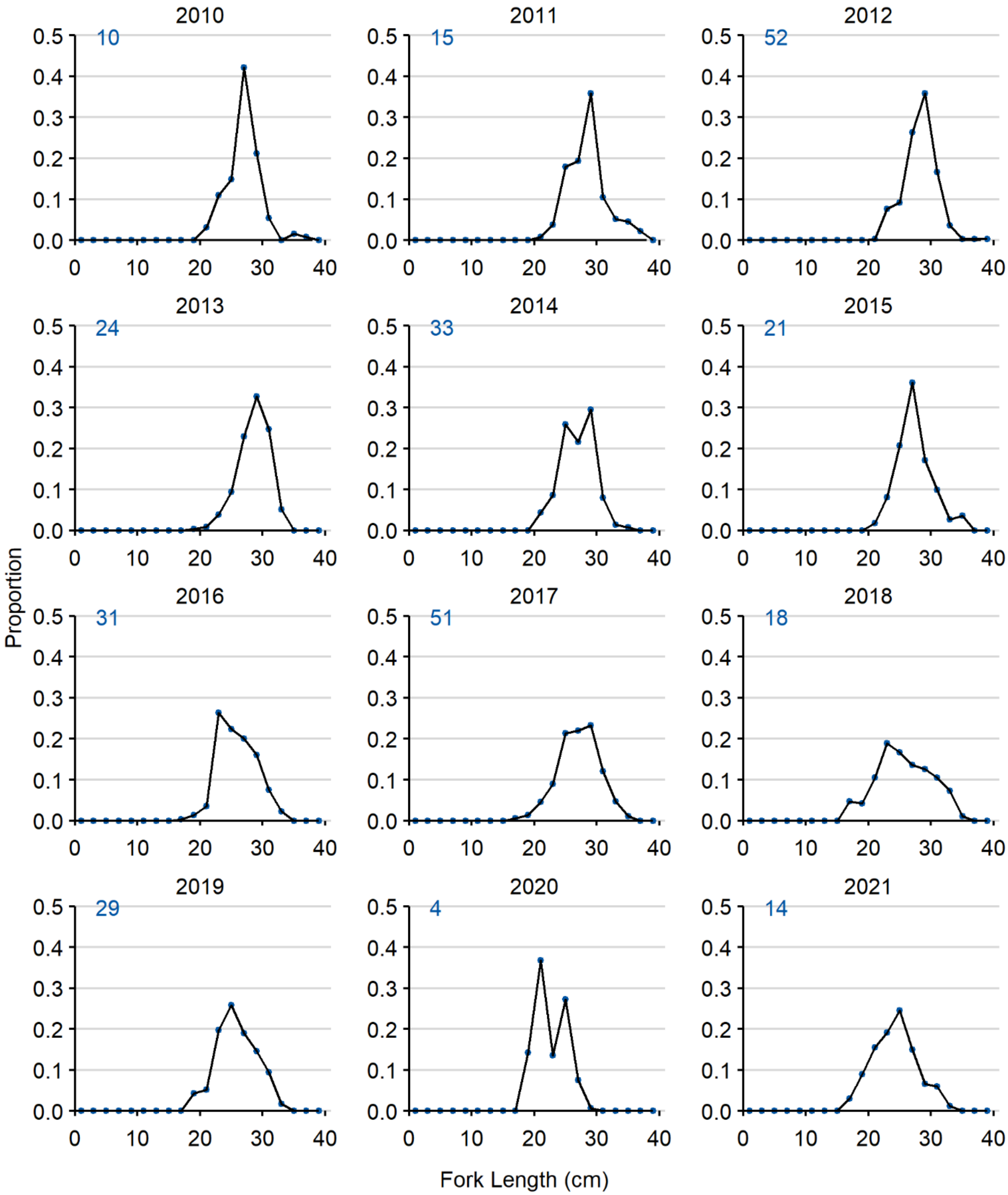


Figure 4-4. Annual proportion at length (cm FL) of *P. auricilla* from the biosampling field data of bottomfishing and bottomfishing / troll mix trips. The number at the upper left corner of each plot is the number of trips that provided *P. auricilla* measurements to the data for that year.

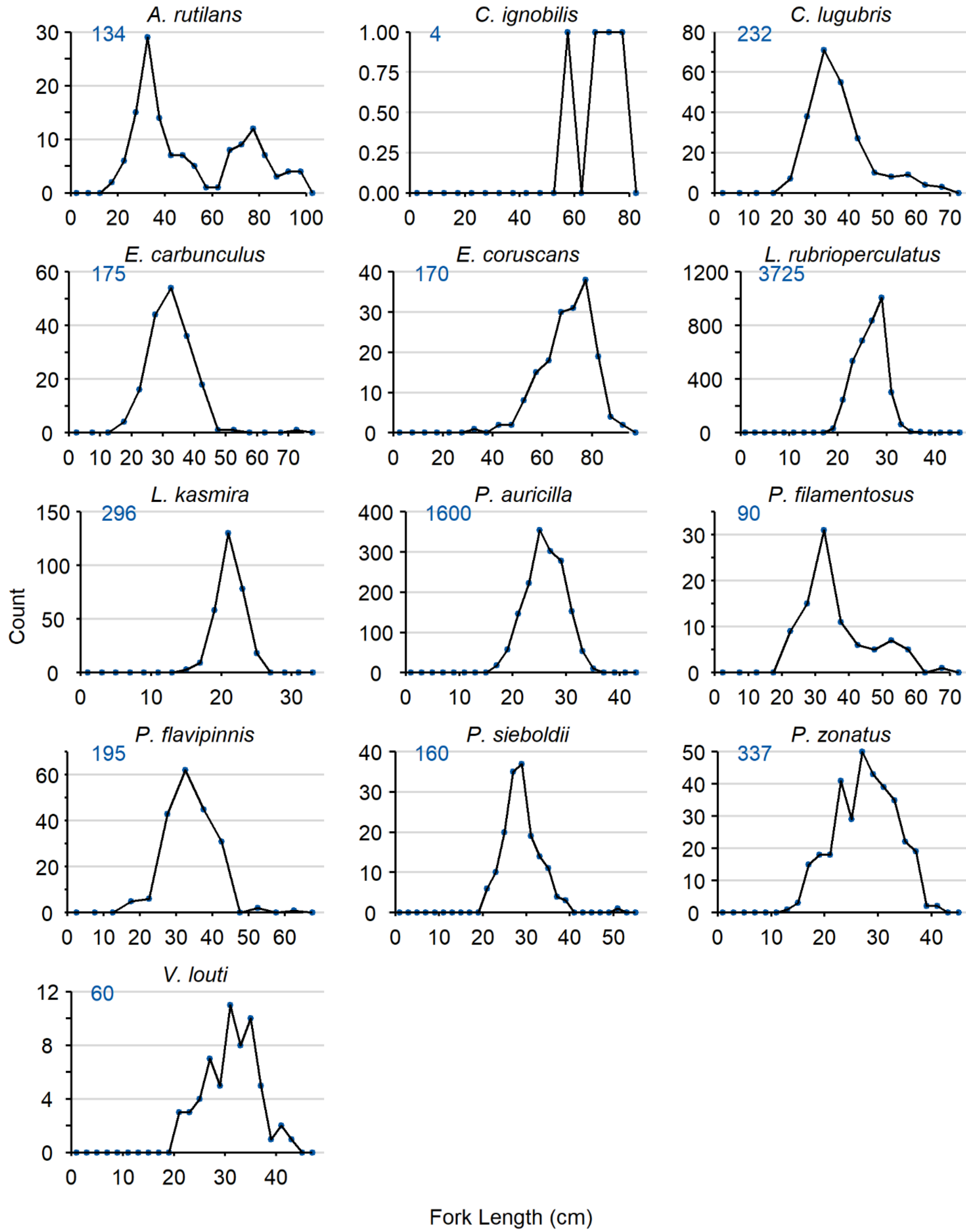


Figure 4-5. BMUS length frequencies recorded in the biosampling field data set for bottomfishing and mixed bottomfishing / troll trips over 2017–2021. The number at the upper left corner of each plot is the number of fish measured for each species 2017–2021.

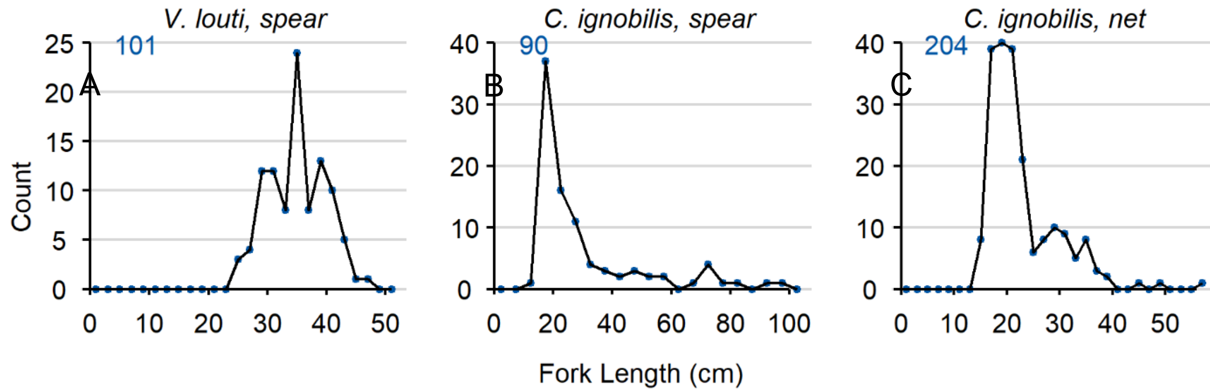


Figure 4-6. Length frequencies recorded in the biosampling field data set from 2017–2021 for (A) *V. louti* spearfishing, (B) *C. ignobilis* spearfishing, and (C) *C. ignobilis* net gears (gillnet, talaya/castnet, and unspecified net). The number at the upper left corner of each plot is the number of fish measured.

5. NOAA Diver Surveys

Fisheries-independent data are available from the diver surveys conducted by NOAA Fisheries Pacific Islands Fisheries Science Center (PIFSC) Ecosystem Sciences Division (ESD). These surveys provide both length and abundance data, mainly for nearshore species. Below is a brief description of the survey protocol. An in-depth description is available in Ayotte et al. (2015).

The Pacific Reef Assessment and Monitoring Program (RAMP) was established in 2000 to provide data on the status and trends over time of the U.S. Pacific coral reef ecosystems. Regions were visited on a biennial cycle from 2000 to 2011, and a triennial cycle starting in 2012. In the early years, a variety of methods were implemented to observe marine life at haphazardly located permanent sites. However, from 2009 onwards, a standardized stationary point count (SPC) and depth-stratified random sampling were implemented, along with a higher level of survey effort. For this reason, emphasis is often placed on survey years since 2009, when considering temporal trends or when standardized effort is required. For Guam, surveys during 2009, 2011, 2014, and 2017 are the primary source of diver survey data, while surveys in 2003, 2005, and 2007 can also be investigated with caution.

Following the depth-stratified random sampling first implemented in 2009, survey sites were randomly selected within strata defined by depth bins (shallow, 0–6 m; mid, 6–18 m; and deep, 18–30 m). All coastlines around Guam were accessible because divers operated from small boats deployed from a larger research vessel (Figure 5-1). For practical and safety reasons, surveys were limited to depths above 30 m. During a typical survey day, a NOAA ship deployed 3 to 5 small boats with divers to survey sites. At each site, two divers each surveyed the volume of a contiguous 15-m diameter cylinder from the seafloor to the surface (Brandt et al., 2009; Smith et al., 2011; Williams et al., 2011). Each diver first listed all observed fish species during an initial 5-minute period and then went through this list, one species at the time, recording number of individuals and estimating sizes of all fish seen within the cylinder. Fish sizes were recorded as total lengths to the nearest cm. Individuals from species not listed during the initial 5-minute period but observed later in the survey were also recorded but classified in a different data category (i.e., non-instantaneous count). Divers were continuously trained between cruises in size estimation using fish cut-outs of various sizes. Diver performance during research cruises was evaluated by comparing size and count estimates between paired divers.

Total density (individuals per area) was estimated by dividing fish counts in each survey by the total surveyed area (353 m^2 from two 15-m diameter survey cylinders). An individual survey consisted of the combined fish counts from the two divers deployed at a single site. Standard deviations were obtained by bootstrapping the diver survey data set by re-sampling survey sites within each sector and applying the weighted mean procedure described above to generate a distribution of mean numerical density.

One clear limitation of this data set is the potential mismatch between the survey domain (limited to 30-m depth) and the greater depth range of certain species. All bottomfish management unit species (BMUS) occur at depths greater than 30 m, and some also inhabit depths shallower than 30 m.

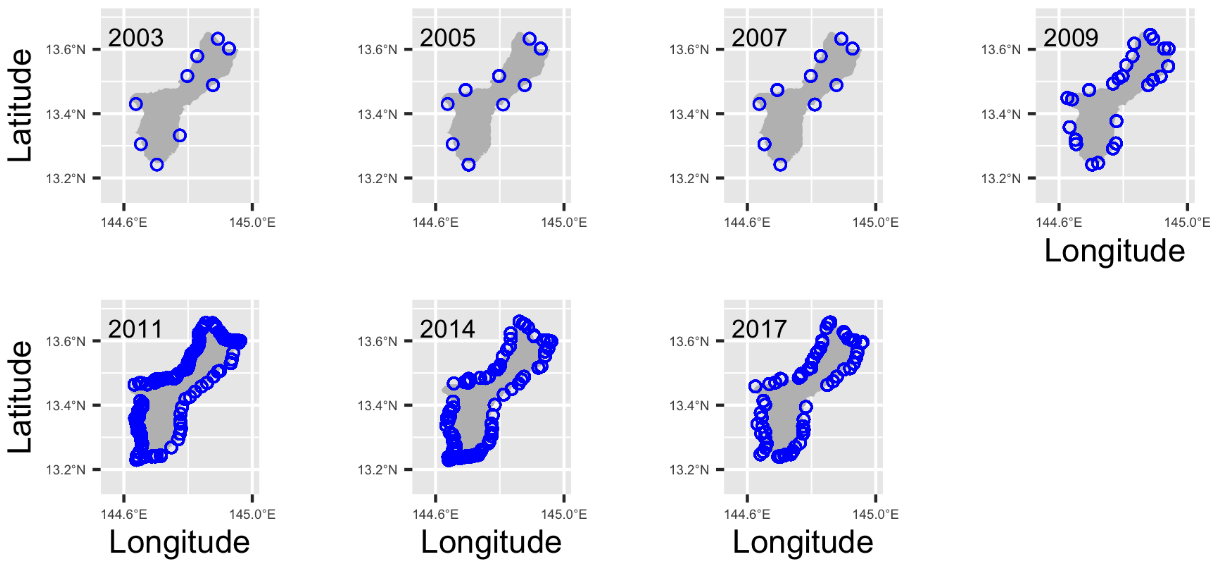


Figure 5-1. Location of diver survey sites in Guam, by year.

5.1 Size data

A total of 214 BMUS were recorded during 7 survey years in Guam, although exclusively from four nearshore species within that complex (Figure 5-2). Only four sightings, all of *V. louti*, came from the first three survey years (2003–2007). Thus, very little data are lost by only considering size data from the more recent survey years (2009–2017) which have standardized survey methods. Three-quarters of the records were *L. kasmira*, and most of the remaining records were *V. louti*. The other two species, *C. ignobilis* and *L. rubrioperculatus*, were rarely encountered by divers.

Due to their rarity in diver surveys, BMUS length observations would need to be aggregated across years to obtain sufficient sample sizes for inclusion in an assessment model. Only a single species in a single year, *L. kasmira* in 2011, provided a sufficient number of size observations from diver surveys for use in a stock assessment (Figure 5-3). Furthermore, only *V. louti* was observed in more than 2 years, and even those observations were extremely rare.

A total of 162 lengths were measured for *L. kasmira* from 2009–2017. The distribution is quite patchy, possibly due to the schooling of similarly-sized individuals, with a mode around 17 cm but notable counts around 12 and 20 cm as well (Figure 5-4). A total of 34 lengths were measured for *V. louti*, with a clear mode around 30 cm and maximum size of around 80 cm. Insufficient sample sizes were available for *C. ignobilis* and *L. rubrioperculatus* to inform length distributions for these species.

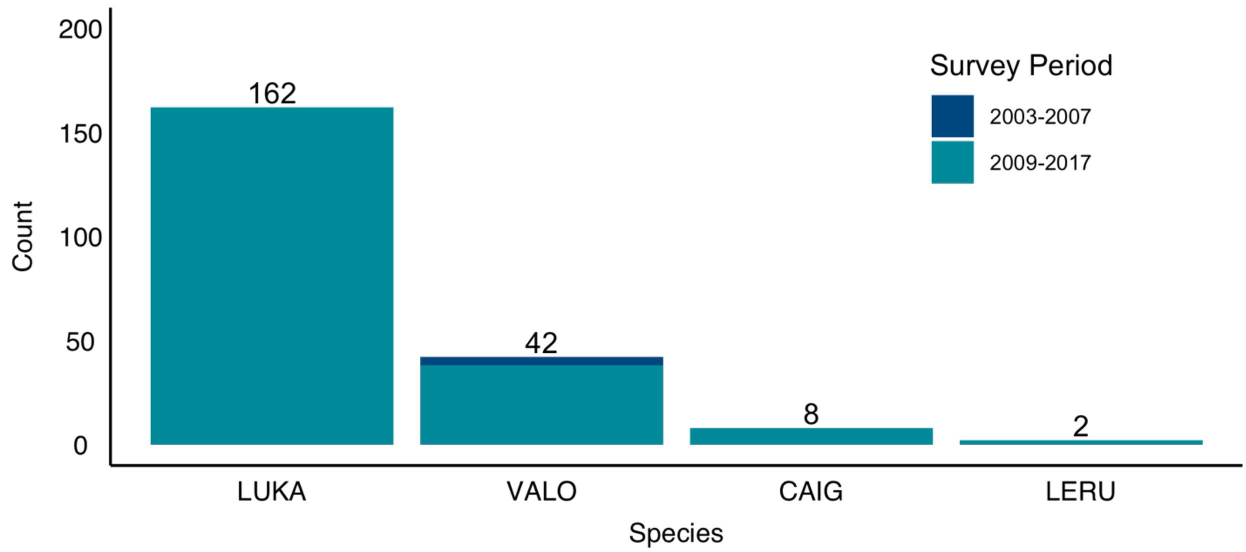


Figure 5-2. Number of observations of BMUS during diver surveys from 2003–2017. Species codes are the first two letters of the genus and species name (see Table 1-1).

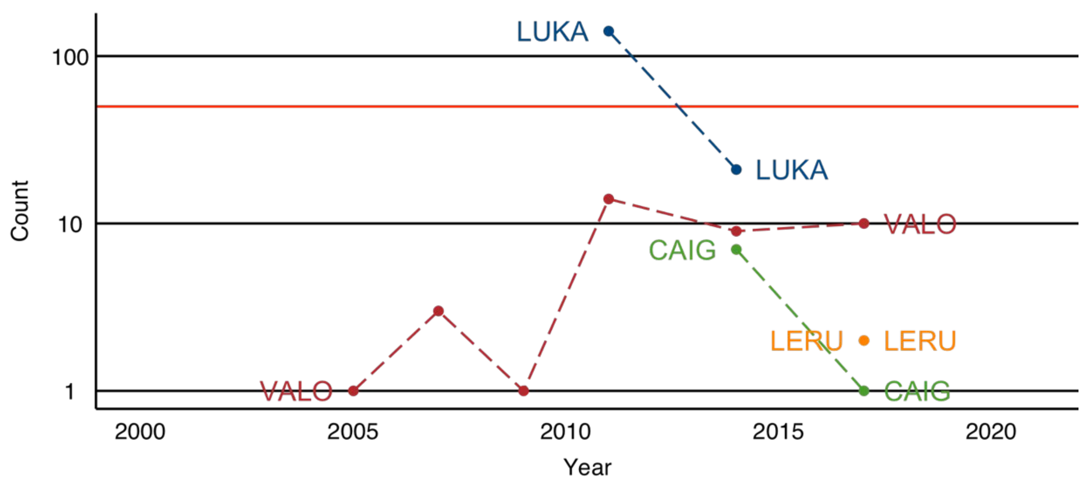


Figure 5-3. Number of observations of BMUS during diver surveys by year. The red horizontal line represents a rough cut-off point to run length-based analyses (50 observations/year). Species codes are the first two letters of the genus and species name (see Table 1-1).

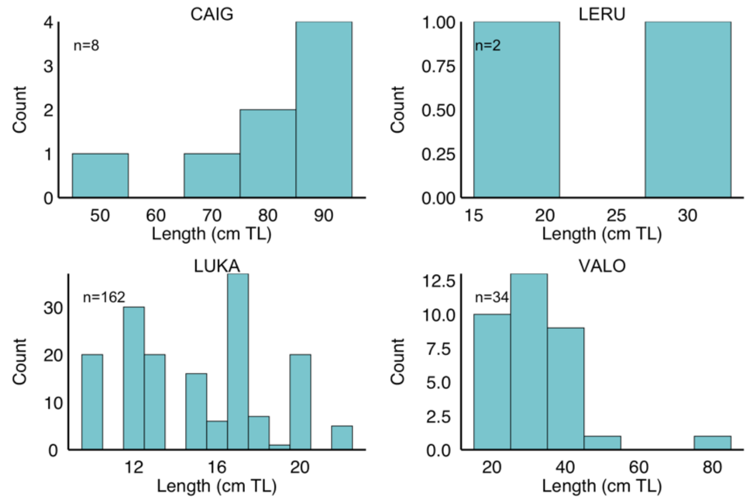


Figure 5-4. BMUS length frequencies from diver surveys (2009–2017).

5.2 Relative abundance

Fish counts from diver surveys can be used directly as a fisheries-independent index of abundance because diver surveys implement a controlled fish count method using trained divers so they do not necessarily need to be standardized to remove the effects of non-abundance related variables. The main weakness of these surveys in relation to BMUS is that they are limited to 30-m depths, which is outside the depth range of most BMUS and only covers a fraction of the habitat for a few of them. Only years when survey methodology was standardized (2009–2017) could be considered in calculating these abundance indices.

Overall, four bottomfish species were observed by divers around Guam (*C. ignobilis, L. rubrioperculatus, L. kasmira,* and *V. louti*). *C. ignobilis* and *L. rubrioperculatus* were only observed three and one times, respectively, and are therefore not further discussed in this section. *L. kasmira* and *V. louti* were observed only slightly more often by divers. *L. kasmira* were recorded on 2% of surveys and *V. louti* on 4% of surveys (Figure 5-5).

For most BMUS and years, the coefficients of variation (CVs) were at least 0.5, which is relatively high (Figure 5-6). CVs are lower for *V. louti* in the three most recent survey years, but overall the rare occurrence of each of these species make abundance indices for them from diver surveys minimally informative.

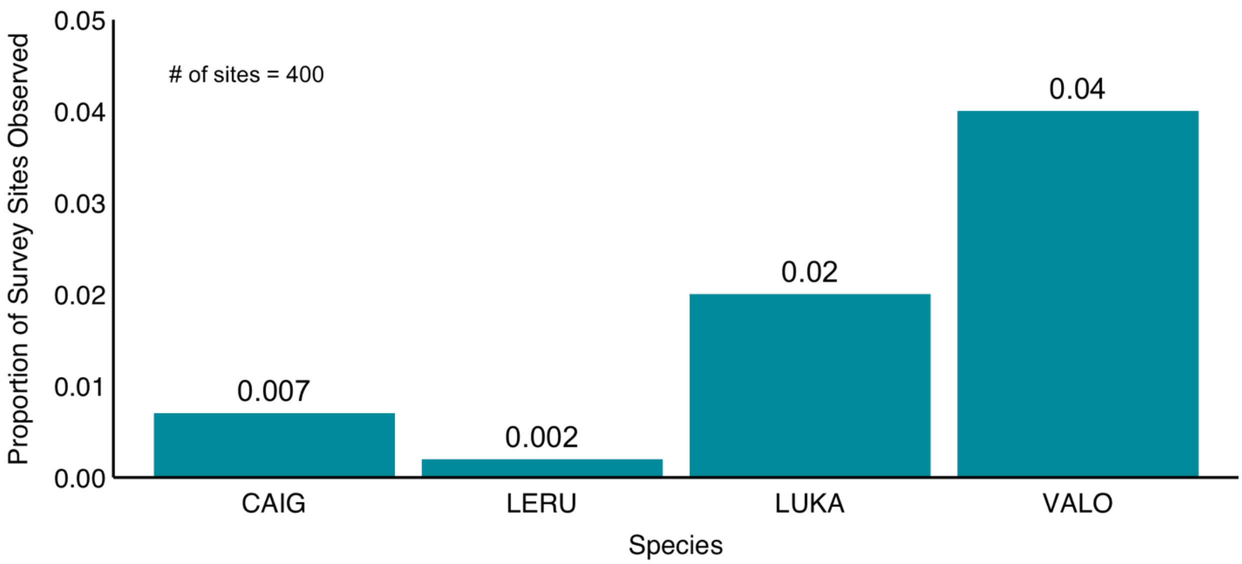


Figure 5-5. Proportion of diver survey sites with a positive species sighting. The number above each bar shows the proportion. Species codes are the first two letters of the genus and species name (see Table 1-1).

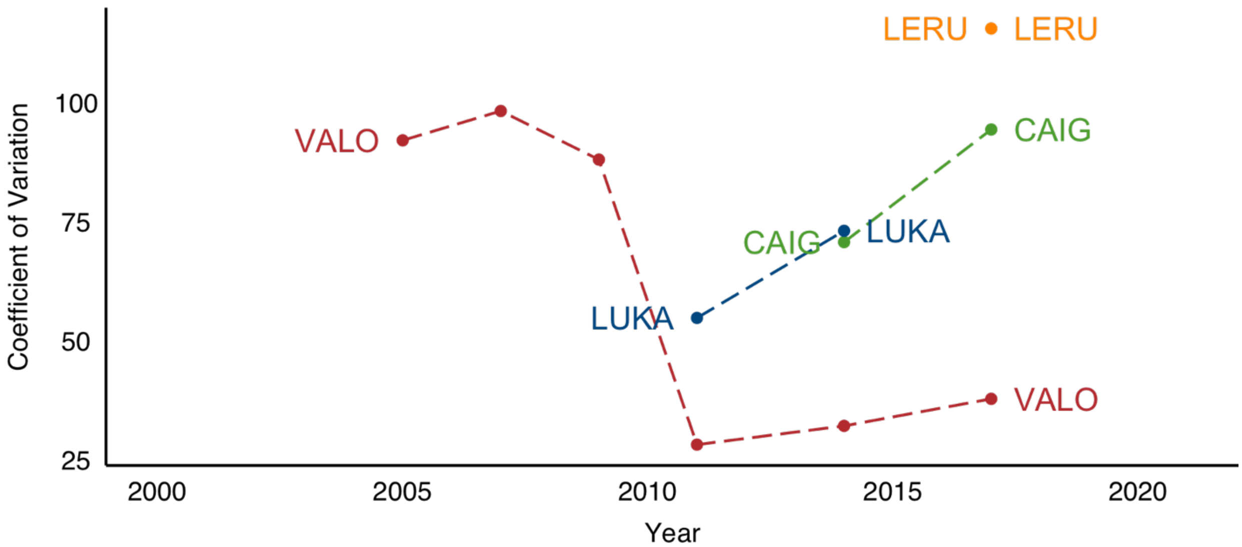


Figure 5-6. Coefficient of variation of relative abundance from diver surveys by species. Species codes are the first two letters of the genus and species name (see Table 1-1).

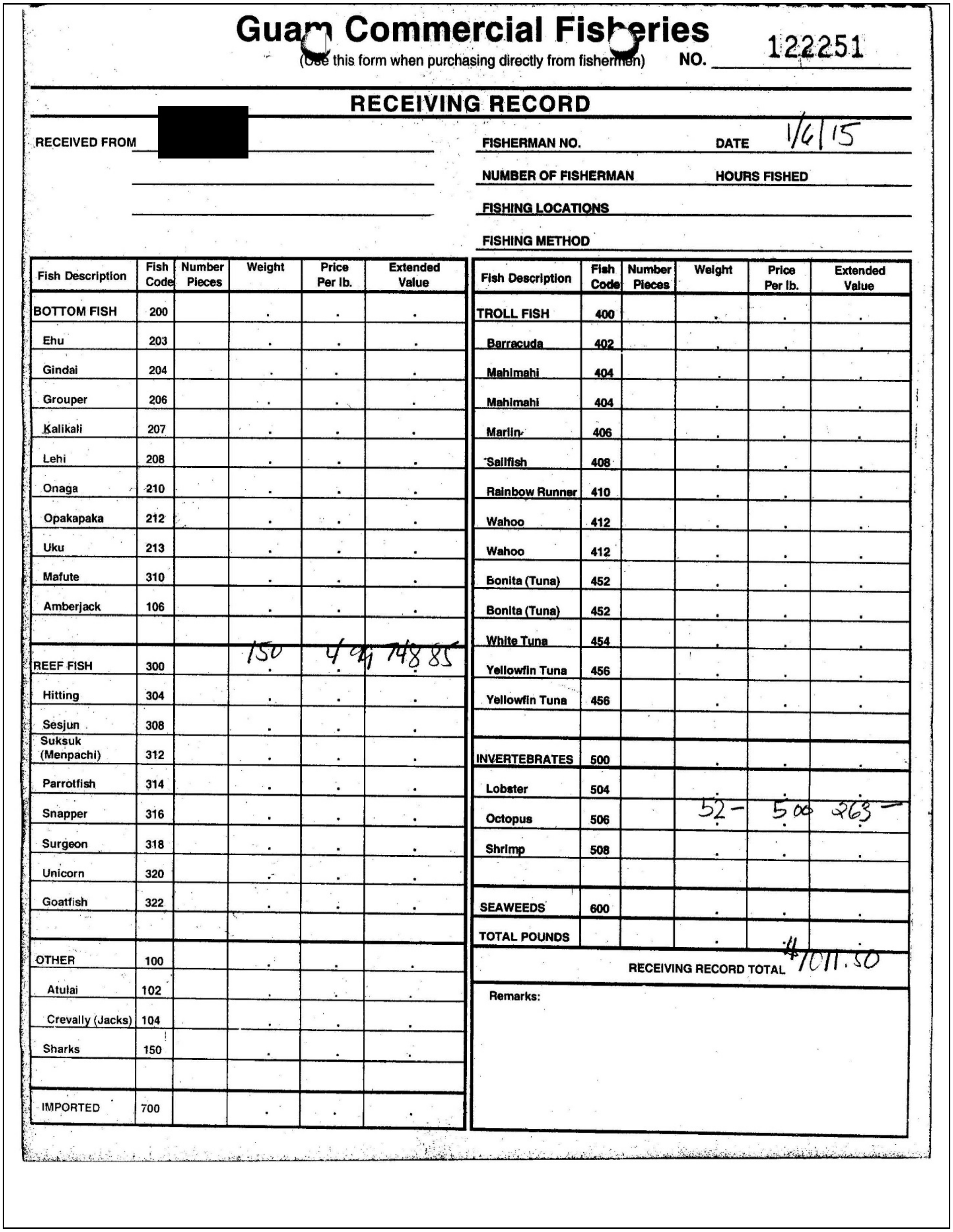
6. Commercial Purchase Invoice Program

The Guam Fishermen's Co-op (the Co-op), established in 1979, provides fresh local fish at a market next to the island's primary fishing port, Hagatna (Agana) Boat Basin. The Co-op purchased catch from local fishers and used paper invoices to record the amount and species or species category of fish bought. The Western Pacific Fisheries Information Network (WPacFIN) began working with the Co-op in 1982 to share and computerize all commercial purchase invoices. Numerous other wholesale fish buyers have participated in the program since 1982, peaking at 11 buyers in 2017. The Commercial Purchase Invoice Program (CPIP) has always been voluntary and participation by fish dealers is variable and challenging to quantify. Because CPIP does not capture non-commercial catch and any commercial catch that is not sold to a participating buyer, it is not expected to provide an accurate estimate of island-wide bottomfish catch.

Guam CPIP data have been used in past stock assessments to provide an estimate of minimum annual landings for aggregated bottomfish management unit species (BMUS). The estimates could also be used for some individual BMUS which are included on the invoice form as common names within a "bottom fish" category: ehu, gindai, kalikali, onaga, and opakapaka, which are assumed to refer to *E. carbunculus*, *P. zonatus*, *P. sieboldii*, *E. coruscans*, and *P. filamentosus*, respectively (Figure 6-1). The other 8 BMUS are not listed by name on the invoice forms and might be recorded as bottom fish, deep bottom fish, grouper, mafute, tagafi, jacks, or snapper, which together comprise approximately half of recorded bottomfishes by weight in the CPIP data. These broad fish groups could also be used to record the individual named BMUS; therefore, it is possible the recorded weights sold for the listed BMUS species are much less than the actual amount purchased.

The Guam CPIP forms also include fields to enter the trip effort in number of fishers and hours fished; in instances when these fields are completed (e.g., hours fished is not 0 or null), it would be possible to compute a relative timeseries of nominal catch per unit effort (CPUE) in lb per hour fished. It is important to note that relying on these nominal CPUE estimates in a stock assessment would likely be problematic for several reasons such as the exclusion of catch identified only to group level and the inability to account for other factors that can drive catch rates within a CPUE standardized model, including gear type, area fished, number of fishers, and time of day. In addition, the fishers who sell their catch to fish buyers and are forthcoming with information regarding how long they fished may not have provided information consistently over the timeseries and may not represent the fishery as a whole. Finally, the biggest obstacle to using these nominal CPUE estimates is that trips with zero bottomfish catches (CPUE = 0) would not be recorded in the CPIP because there would have been no catch for the fisher to sell.

Finally, the CPIP forms include a field for the number of fish for each species or species category. Thus, it would be possible to either calculate a trip-level average weight per fish or filter the records for instances when only one fish was sold to provide individual fish size information. These individual sizes could then inform the timeseries of size compositions within an age-structured assessment model. The number of fish sold was recorded in approximately only 31% of all sale records of the six identified BMUS, so the average annual sample size of individual weight estimates ranged from 4.6 for *C. lugubris* to 20.3 for *E. coruscans*. Of the invoice records of BMUS where the number of fish sold was recorded, 36% were for a single fish, yielding an average annual sample size of individual weights from 1.8 for *P. sieboldii* to 10.9 for *E. coruscans*.



Guam Commercial Fisheries

(Use this form when purchasing directly from fishermen) NO. 122251

RECEIVING RECORD

RECEIVED FROM [redacted]

FISHERMAN NO. DATE 1/6/15

NUMBER OF FISHERMAN HOURS FISHED

FISHING LOCATIONS

FISHING METHOD

Fish Description	Fish Code	Number Pieces	Weight	Price Per lb.	Extended Value
BOTTOM FISH	200		.	.	.
Ehu	203		.	.	.
Gindai	204		.	.	.
Grouper	206		.	.	.
Kalikali	207		.	.	.
Lehi	208		.	.	.
Onaga	210		.	.	.
Opakapaka	212		.	.	.
Uku	213		.	.	.
Mafute	310		.	.	.
Amberjack	106		.	.	.
REEF FISH	300		150	4 99	748 85
Hitting	304		.	.	.
Sesjun	308		.	.	.
Suksuk (Menpachi)	312		.	.	.
Parrotfish	314		.	.	.
Snapper	316		.	.	.
Surgeon	318		.	.	.
Unicorn	320		.	.	.
Goatfish	322		.	.	.
OTHER	100		.	.	.
Atulai	102		.	.	.
Crevally (Jacks)	104		.	.	.
Sharks	150		.	.	.
IMPORTED	700		.	.	.

Fish Description	Fish Code	Number Pieces	Weight	Price Per lb.	Extended Value
TROLL FISH	400		.	.	.
Barracuda	402		.	.	.
Mahimahi	404		.	.	.
Mahimahi	404		.	.	.
Marlin	406		.	.	.
Sailfish	408		.	.	.
Rainbow Runner	410		.	.	.
Wahoo	412		.	.	.
Wahoo	412		.	.	.
Bonita (Tuna)	452		.	.	.
Bonita (Tuna)	452		.	.	.
White Tuna	454		.	.	.
Yellowfin Tuna	456		.	.	.
Yellowfin Tuna	456		.	.	.
INVERTEBRATES	500		.	.	.
Lobster	504		.	.	.
Octopus	506		52 -	5 00	263 -
Shrimp	508		.	.	.
SEAWEEDS	600		.	.	.
TOTAL POUNDS			.	.	.

RECEIVING RECORD TOTAL $1011.50

Remarks:

Figure 6-1. An example Guam Commercial Fisheries 2015 purchase invoice form.

7. Historical Catch Information

The native inhabitants of Guam and the Northern Mariana Islands were skilled mariners and fishers; in addition to fishing for pelagic species such as tunas, billfishes, and mahimahi, they likely used baited hooks to catch demersal species including groupers, snappers, and emperors beyond the reef (Amesbury, 2013). Formal Spanish colonization of the Mariana Islands began in 1668, and violence and repression of native culture resulted in the eradication of sailing canoes, and the practices of canoe building and fishing from canoes (Amesbury and Hunter-Anderson, 2003). By the late 1800s through at least 1955, fishing was largely limited to areas within the reef lagoon; some fishing for pelagics began during the Japanese occupation in 1941–1945 (van Pel, 1955; Myers, 1993; Amesbury and Hunter-Anderson, 2003; Higuchi, 2007). During meetings with the Guam fishing community in January 2023, fishers confirmed that hook-and-line fishing was done only in shallow water in the 1950s, because fishers did not use reels that would enable more line and deeper fishing. Instead, fishing line was retrieved by hand and wrapped around a bottle for storage on the boat.

In 1963, the Guam Department of Agriculture and Wildlife Resources (DAWR) reported on recommendations to develop the commercial fishing industry. The report referenced bottomfishing and deepwater trap fishing that had been conducted on an experimental basis around Guam, including at Galvez Bank (concluding that fishing was “good” in that area; DAWR, 1963b). A listing of locally caught and marketed fish did not include any of the deepwater snapper species or potential bottomfish management unit species (BMUS), except for mafute and lililuke (emperors, potentially including *L. rubrioperculatus*) and tarakito (mid- to larger size Carangidae, potentially including *C. lugubris* or *C. ignobilis*; DAWR, 1963b; Kerr, 1990). DAWR began conducting aerial (helicopter) surveys and creel survey interviews in 1962 to monitor fishing around Guam. Although no bottomfishers were interviewed until the July 1964–June 1965 time period (a.k.a. the 1965 fiscal year, FY), bottomfishing activity was reported in the aerial surveys at fairly consistent, yet low occurrence in each annual report since the inception of the survey (DAWR, 1963a, 1964, 1965). Creel survey interviews constituted a small sample of bottomfishers each year until the 1969–1970 FY when the first published estimate of annual bottomfish (of all species) landed was 6,296 lb (Figure 7-1; DAWR 1966, 1967, 1968, 1969, 1970). Additional harvest of bottomfishes from exploratory handlining around Guam and on the offshore banks occurred between January 1967 and June 1969, and was reported by species in Ikehara et al. (1970). DAWR produced annual bottomfish landings estimates from 1970–1978 ranging from 3,000 – 39,000 lb, although the high value of 39,000 in FY 1977 was estimated from incomplete creel survey coverage (DAWR, 1970, 1971, 1972, 1975, 1976; Ralston, 1979). Estimated annual landings for calendar years 1980 and 1981 are reported in the original Fishery Management Plan for Bottomfish and Seamount Groundfish Fisheries of the Western Pacific Region (WPRFMC 1986). An additional 570 lb of bottomfishes were caught from Guam and the surrounding banks during exploratory fishing activities aboard the *FV Typhoon* in 1980 (Section 8.3).

Annual landings estimates are not available by species before 1982. However, several exploratory fishing projects identified bottomfishing catch to species level, providing relative proportions of each species in the catch that may be useful in calculating species-level landings. From 1967–1969, exploratory fishing using bottom handline, bottom longline, trolling, and mackerel jigging was performed from the 11.3 m (37 ft) F/V *Panglau Oro* in the waters around Guam and on several adjacent banks (Ikehara et al., 1970). Most of the bottomfishing was done at 148–220 m (486–720 ft) water depth. Catch of the most common species, including 9 BMUS, together with calculated relative percent of the total bottom handline catch, by weight, are given in Table 7-1. The remaining four BMUS (*C. ignobilis*, *L. rubrioperculatus*, *L. kasmira*, and *V. louti*) were reported caught by bottom handline, but species-level catches were not specified in Ikehara et al. (1970) because the report focused primarily on the most commonly caught species. Relative species composition estimates, by weight, are also available from 1978 NOAA R/V *Townsend Cromwell* handline surveys of 12 sites off Coco's Island and the banks southwest of Guam (see Section 8.2). Based on this small sample size (137 kg total bottomfishes, including catch estimated using average fish weights because not all fish were weighed), the dominant BMUS caught, by weight, were *C. lugubris* (21.4%) and *P. zonatus* (14.4%; Table 7-2). Exploratory bottom handline fishing from the 23 m (75 ft.) F/V *Typhoon* of the seamounts and islands spanning the Mariana Archipelago May 1980 to January 1981 (Hosmer and Kami, 1981; Section 8.3) reported species compositions and average fish size, including records of all BMUS except *L. rubrioperculatus* (Table 7-3). *P. zonatus* and *C. lugubris* were the most prevalent bottomfish species caught, accounting for 21.5 and 18.1%, respectively, of total bottom handline catch by weight. Note common species names given by Ikehara et al. (1970) and Hosmer and Kami (1981) are generally consistent with currently used Hawaiian names; however, many of the scientific names have been updated as the study of deepwater snapper taxonomy has advanced (WoRMS Editorial Board, 2022).

By 1982, the DAWR Boat-Based Creel Survey Program (BBS) was fully operational and served as the primary source for fisheries data from 1982–2021. Based on the history of the fishery, and the published reports available (Table 7-3), it is apparent the BMUS stocks sustained some exploitation before the BBS began. We present these data here in order to represent the history of the resource as accurately as possible.

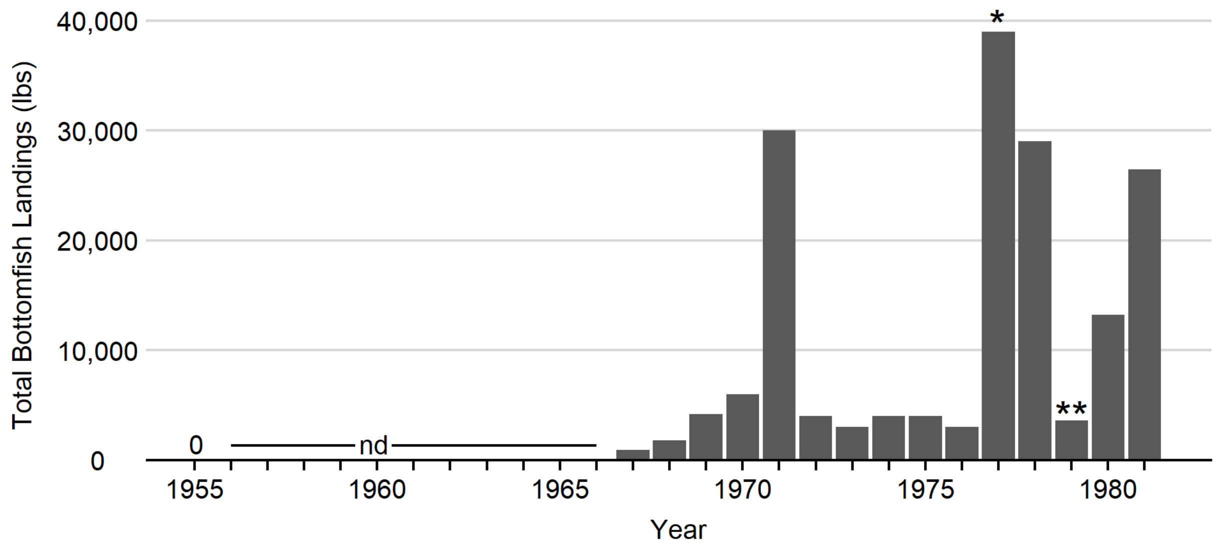


Figure 7-1. Estimated total bottomfish landings (lb) 1955–1981. Total bottomfish landings were reported equal to 0 in 1955, and no data (nd) are available for 1956–1965. Landings from 1967–1969 include recorded bottomfish catches from the F/V *Panglau Oro* exploratory fishing surveys. Landings estimates (*) from 1977 were based on incomplete survey data, and 1979 estimates (**) are from commercial purchase invoices only (Ralston, 1979; Hamm et al., 1986).

Table 7-1. Bottomfish catch by weight, number, and % total bottom handline catch (by weight) from the F/V *Panglau Oro* experimental fishing around Guam, 1967–1969 (Ikehara et al., 1970).

Species (given)	Species (presumptive)	Weight (kg)	Number	% Bottom handline catch (by weight)
Onaga (*E. carbunculus*)	*E. coruscans*	1959	316	23.1
Lehi (*A. rutilans*)	*A. rutilans*	1471	381	17.3
Large grouper (*Epinephelus* sp.)	*Epinephelus spp.*	1001		11.8
Black carangid (*C. lugubris*)	*C. lugubris*	514	194	6.1
Gindai (*Rooseveltia brighami*)	*P. zonatus*	450	483	5.3
Yellow-tail kalikali (*P. auricilla*)	*P. auricilla*	440	681	5.2
Red snapper (*L. bohar*)	*L. bohar*	415	62	4.9
Pink opakapaka (*P. microlepis*)	*P. filamentosus*	318	161	3.7
Ehu (*E. marshi*)	*E. carbunculus*	257	208	3
Amberjack (*Seriola* sp.)	*Seriola spp.*	240	59	2.8
Yellow eye opakapaka (*P. flavipinnis*)	*P. flavipinnis*	178	155	2.1
Pink kalikali (*P. siebondii*)	*P. sieboldii*	127	173	1.5

Table 7-2. NOAA R/V *Townsend Cromwell* handline survey catch of BMUS around Guam, May–June 1978.

Species	Number	% Total bottomfish catch (by weight)
C. lugubris	6	21.4
P. zonatus	23	14.4
P. flavipinnis	9	7.0
P. auricilla	17	6.1
A. rutilans	3	5.7
E. carbunculus	5	3.3
P. filamentosus	2	2.6
L. kasmira	8	0.3

Table 7-3. BMUS catch by weight, number, and % total bottom handline catch (by weight) from the F/V *Typhoon* exploratory fishing of the islands and seamounts of the Mariana Archipelago, 1980–1981.

Species (given)	Species (presumptive)	Weight (kg)	Number	% Bottom handline catch (by weight)
Roosevelt-i.e. (*sic*) *brighami* (gindai)	*P. zonatus*	1071.3	809	21.5
C. lugubris (ulue)	*C. lugubris*	900.9	305	18.1
E. carbunculus (onaga)	*E. coruscans*	417.3	62	8.4
E. marshi (ehu)	*E. carbunculus*	282.1	287	5.7
P. filamentosus (opaka)	*P. filamentosus*	204.3	133	4.1
P. auricilla (kalekale)	*P. auricilla*	195.2	185	3.9
P. flavipinnus (*sic*) (yelloweye opaka)	*P. flavipinnis*	123.1	53	2.5
A. rutilans	*A. rutilans*	85.6	18	1.7
C. ignoblis (*sic*)	*C. ignobilis*	41.2	52	0.8
V. louti	*V. louti*	8.2	5	0.2
L. kasmira	*L. kasmira*	5.9	16	0.1
P. siebo·;d-; (*sic*)	*P. sieboldii*	0.4	3	<0.1

Table 7-4. A partial bibliography of pre-1982 Guam bottomfish fishery information.

Title	Description / Comments
van Pel, H. (1955). A plan for the development of fisheries in Guam. South Pacific Commission, Noumea, New Caledonia.	Fishing beyond the reef is very rare, no mention of bottomfishing other than suggestions that a trap fishery in the shallow waters beyond the reef may be viable.
DAWR (1963). Development of commercial fishing industry in Guam. Project No. 404.	Mention "experimental" bottomfishing July 1962 to June 1963. Describe plans for developing more infrastructure to support boat-based fisheries.
DAWR. (1963–1976). Guam survey of island fish Populations and Fishing Methods. Project No. FW-2-R.	Annual reports describing DAWR activities, including number of interviews, catch rates, aerial effort / megafauna surveys, and diver transects. Some years include expanded landings estimates.
Ikehara, I. I., Kami, H. T., & Sakamoto, R. K. (1970). Exploratory fishing survey of the inshore fisheries resources of Guam. South Pacific Commission Fourth Technical Meeting of Fisheries.	Experimental fishing surveys on the *Panglau Oro* around Guam and the Banks 1967–1969. Total catch and catch rates by area and overall species composition.
Ralston, S. (1979). A Description of the Bottomfish Fisheries of Hawaii, American Samoa, Guam, and the Northern Marianas. A report submitted to the Western Pacific Regional Fisheries Management Council. Honolulu, Hawaii.	Total estimated bottomfish landings 1968–1978.
Hosmer, A. & Kami, H. (1981). PTDF seamount groundfish development project—Guam, May 1980, January 1981, FV Typhoon. Aquatic and Wildlife Resources, Guam. 25 p.	Exploratory fishing survey of seamounts and islands of the Mariana Archipelago, 1980–1981, primarily handline. Species comps and average size aggregated over all areas, total bottomfish catch by area.
Hamm, D. C., Quach, M. M. C., & Kassman, T. T. (1986). Fishery Statistics of the Western Pacific, Volume II. Administrative Report H-86-20.	Commercial purchase invoice landings for 1979–1983.
WPRFMC. (1986). Fishery management plan for the bottomfish and seamount groundfish fisheries of the Western Pacific Region. Honolulu, Hawaii.	Total estimated bottomfish landings 1980–1984.
Myers, R. F. (1993). Guam's Small-Boat-based Fisheries. Marine Fisheries Review 55(2): 117–128.	Landings estimates 1980–1991, overall species composition (sum 1980–1991). Suggest bottomfishing was established by "mid-1960s".

8. Fisheries-Independent Data

Fisheries-independent data, such as scientific surveys designed to estimate relative abundance and size composition, constitute an important data stream in the stock assessments for many large commercial U.S. fisheries. The NOAA Diver Survey (Section 5) is the only standardized fisheries-independent survey in Guam, and was designed to capture reef fishes, not bottomfishes. There have been several independent research projects involving bottomfishes in Guam and the other Mariana Islands with a range of objectives and methods, including exploratory fishing to determine feasibility of developing commercial fisheries, catch and effort data for stock productivity estimation, pilot fisheries-independent surveys, and collection of specimens for life history research. Most of these projects included small sample sizes, covered just a few years, and followed inconsistent methods over time. As a result, incorporating these data into stock assessments for the Guam bottomfish management unit species (BMUS) is likely not possible. We present a summary description of these data here in order to represent all data available for the resource as accurately as possible.

8.1 Exploratory fishing, F/V *Panglau Oro*, 1967–1969

From 1967–1969, exploratory fishing using bottom handline, bottom longline, trolling, and mackerel jigging was performed from the 11.3 m (37 ft) F/V *Panglau Oro* in the waters around Guam and on several adjacent banks (Ikehara et al., 1970). Most of the bottomfishing was done at 148–220 m (486–720 ft) water depth. Total bottomfish catch and effort data were reported by depth range and area. Catch was reported over the duration of the study by species only for the most abundant species encountered, which included 9 of the 13 BMUS (Table 7-1).

8.2 Handline fishing, R/V *Townsend Cromwell*, 1978

Catch and effort handline fishing data for bottomfishes were collected by NOAA R/V *Townsend Cromwell* at 12 sites off Coco's Island and the banks southwest of Guam during May–June 1978 (Figure 8-1; Pacific Islands Fisheries Science Center, 2022). Depths ranged from 25–135 fathoms (150–810 ft), and average site depth was 80 fathoms (470 ft). A total of 129 fish were caught during bottom handline fishing. The most commonly encountered BMUS were *P. zonatus* and *P. auricilla* (Table 7-2). There were no individual size (length or weight) observations. Catch weight by species was not reported for all sites; therefore, estimated relative proportion of BMUS by weight require assumptions regarding average fish weights.

8.3 Exploratory fishing, F/V *Typhoon*, 1980–1981

The Pacific Tuna Development Foundation (PTDF) funded exploratory fishing surveys on the 23 m (75 ft) F/V *Typhoon* of the seamounts and islands spanning the Mariana Archipelago from Farallon de Pajaros in the north to Santa Rosa Banks in the south during May 1980 to January 1981 (Hosmer and Kami, 1981). The primary objective of the project was to investigate fishing methods to best exploit demersal fishes, with an emphasis on alfonsin (*Beryx splendons*), and determine whether such fisheries would be economically feasible. Bottomfishing was conducted using primarily handline gear with hydraulic reels at 40–640 m depths. Bottomfish catches from Guam, Rota Banks, Galvez Banks, and Santa Rosa Banks totaled 260 kg during 1980. Species compositions and average fish size, including records of all BMUS except *L. rubrioperculatus*, were reported for the entire Mariana Archipelago (Table 7-3). *P. zonatus* and *C. lugubris* were the most prevalent bottomfish species caught, accounting for 21.5 and 18.1%, respectively, of total bottom handline catch by weight. The survey did not encounter any *B. splendons* and concluded that based on catch rates, commercial bottomfishing from a large vessel such as the F/V *Typhoon* would not be financially sustainable.

8.4 Handline fishing, R/V *Townsend Cromwell*, 1982–1984

During the Resource Assessment Investigation of the Mariana Archipelago (RAIOMA), the NOAA R/V *Townsend Cromwell* conducted bottom handline fishing at 22 islands and banks of the Mariana Islands during several cruises from May 1982 through June 1984. Fishing was done at 31 sites around Guam and the surrounding banks in May/June 1982 and April 1984 (Figure 8-1). The survey caught 169 bottomfish, including 139 BMUS (Table 8-1). *P. auricilla* and *P. zonatus* were the most numerous BMUS encountered, comprising 35 and 29%, respectively, of all bottomfish caught around Guam by number. Individual fish lengths were also recorded.

8.5 Shallow bottomfishing along a fishing pressure gradient at Guam offshore banks, F/V *Ataloa*, 1997–1999

The Guam Department of Agriculture and Wildlife Resources (DAWR) conducted a series of ten shallow bottomfishing trips from October 1997 to June 1999 to compare catch among several offshore banks: Bank A, rarely fished, located approximately 200 km west of the Island of Guam; White Tuna Bank, moderately fished, located south of Guam; and Galvez Bank, a heavily fished area (Figure 2-1). The primary target of the study was *L. rubrioperculatus*, which was chosen as an indicator species to estimate relative fishing pressure. However, all fish caught were identified to species, measured for length, and weighed. Depths fished ranged from approximately 30 to 220 m.

Only four BMUS were caught (*C. lugubris*, *L. rubrioperculatus*, *L. kasmira*, and *V. louti*); however, at 731.4 kg, they represented 53.1% of total catch by weight (Table 8-2). There was a distinct difference in species composition across the banks. *C. lugubris* was 29.5% of the catch by weight at Bank A, versus 5.4% or lower at the more heavily fished banks. On the other hand, *L. rubrioperculatus* was caught most at the moderately fished White Tuna Bank—46.4% by weight versus 21.9% at Bank A and 12.6% at Galvez Bank. *L. kasmira* and *V. louti* were lesser contributors.

8.6 Pilot fisheries-independent survey for bottomfish in waters around Guam, 2009–2014

Pacific Islands Fisheries Group (PIFG), under contract to NOAA Fisheries, implemented a pilot fisheries-independent survey for bottomfish in waters around Guam and the main Hawaiian Islands (MHI) from 2009–2014 (Pacific Islands Fisheries Group, 2010, 2012; Kendall Enterprises, 2014). The project was part of a larger NOAA-funded effort that included bottomfish tagging and expanded fisheries-dependent sampling in the MHI, Guam, and CNMI. The pilot survey in Guam included 83 spatially stratified random bottomfishing sites on Galvez Bank (average depth 260 ft, range 180–440 ft) that were surveyed by the NOAA Ship *Oscar Elton Sette* using remote underwater video camera in early 2010. Local Guam fishing boats were contracted to perform bottomfishing operations at each survey site in summer 2010, 2012, and 2014. Trained observers identified catch to species, recorded individual lengths and weights, and collected biological samples for life history research. Blacktip grouper (*Epinephelus fasciatus*) was the most frequently caught species over all years, accounting for 40% of total catch. *L. rubrioperculatus* was the most commonly encountered BMUS (23% by number of total catch over all years; Table 8-2). Most BMUS were rarely or never caught during the surveys, primarily owing to the shallow depths fished. The primary objective of the pilot fisheries-independent survey for bottomfish was to explore survey methodology; as a result, fishing practices, vessels, fishers, time of year, and fishing sites were not standardized between years (Kendall Enterprises, 2014); hence using these data as a timeseries within a stock assessment, either in terms of abundance or fish size, would not be advisable.

8.7 Specimen collection for life history research, R/V *Oscar Elton Sette*, 2014

NOAA Fisheries Pacific Island Fisheries Science Center (PIFSC) scientists collected BMUS using handline gear around Guam and the surrounding banks in July and August 2014. The primary objective of these research fishing activities was to collect biological samples for age-growth, morphometry, and reproduction/maturity studies. The total number of BMUS caught was small, ranging from one each *L. rubrioperculatus* and *V. louti*, to 22 *P. auricilla* (Table 8-3). *Caranx* species were not retained.

Table 8-1. RAIOMA bottomfish catch around Guam, 1982–1984.

Species	Number	Average Length, cm
P. auricilla	49	29.9
P. zonatus	41	35.3
E. carbunculus	11	34.4
C. lugubris	10	56.9
P. flavipinnis	9	39.7
P. filamentosus	8	40.3
A. rutilans	6	55.0
P. sieboldii	3	33.1
E. coruscans	1	78.6
L. rubrioperculatus	1	34.3

Table 8-2. Catch from shallow bottomfishing on the F/V *Ataloa*, 1997–1999.

Species	Catch (kg)		
	Bank A	White Tuna Bank	Galvez Bank
C. lugubris	221.0	15.3	9.9
L. rubrioperculatus	163.8	132.3	43.2
L. kasmira	65.8	35.9	27.2
V. louti	7.0	5.9	4.1
All other species	290.3	96.0	258.7

Table 8-3. Catch from pilot fisheries-independent surveys of Galvez Bank, 2010–2014. For each year, *N* is the number of stations surveyed.

Species	Catch (Number)				Percent Total Catch
	2010 (*N* = 83)	2012 (*N* = 83)	2014 (*N* = 77)	All Years	
BMUS					
A. rutilans	1	0	0	1	< 1
C. ignobilis	0	0	0	0	0
C. lugubris	3	0	0	3	< 1
E. carbunculus	3	0	0	3	< 1
E. coruscans	3	0	0	3	< 1
L. rubrioperculatus	83	53	127	263	23
L. kasmira	31	6	23	60	5
P. auricilla	30	0	0	30	3
P. filamentosus	0	0	0	0	0
P. flavipinnis	1	0	0	1	< 1
P. sieboldii	5	0	0	5	< 1
P. zonatus	0	0	0	0	0
V. louti	42	12	6	60	5
Non-BMUS					
Epinephelus fasciatus	85	80	281	446	40
All other species	117	29	106	252	22

Table 8-4. BMUS catch from PIFSC life history research specimen collection of Guam and the surrounding banks, July–August 2014.

Species	Catch	
	Total Number	Total Weight (kg)
A. rutilans	6	9.9
E. carbunculus	13	6.2
E. coruscans	9	34.6
L. rubrioperculatus	1	0.2
L. kasmira	2	0.3
P. auricilla	22	10.4
P. filamentosus	5	6.8
P. flavipinnis	20	14.9
P. sieboldii	8	4.8
P. zonatus	18	8.3
V. louti	1	0.2

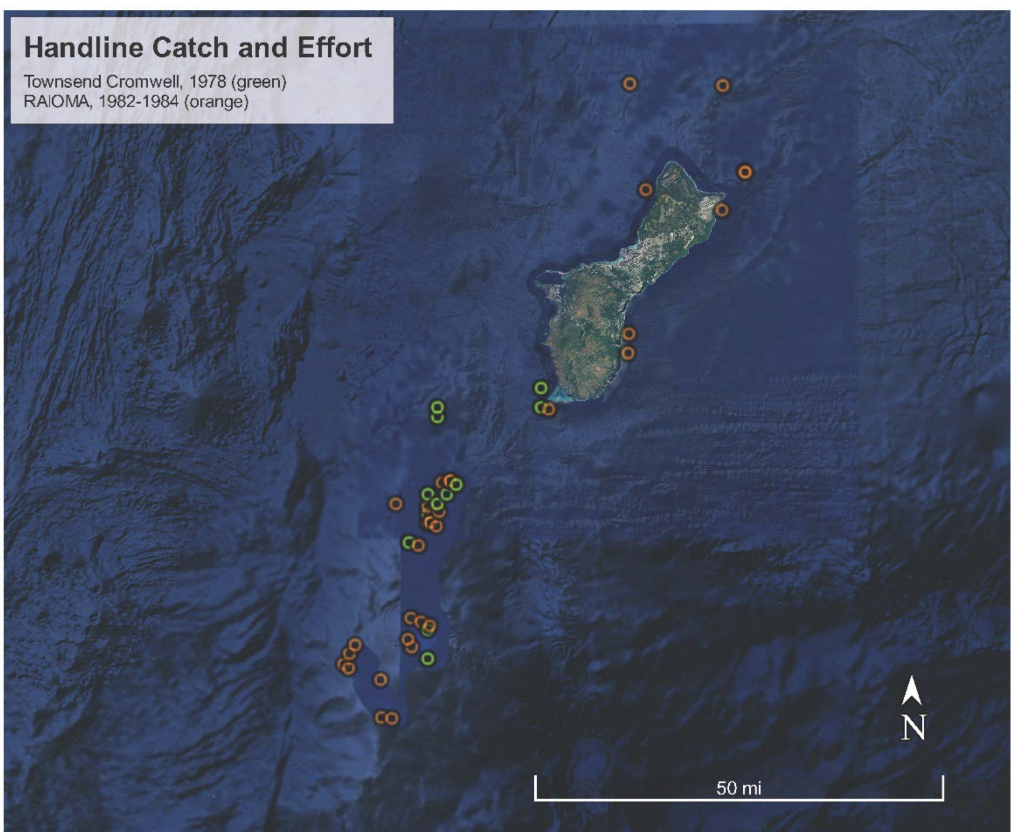


Figure 8-1. NOAA R/V *Townsend Cromwell* bottom handline fishing around Guam during 1978 (green) and 1982–1984 (orange).

9. Voluntary Self-Reporting

Fisheries data collection through voluntary self-reporting relies on the fishers (or fish dealers) to provide information on their catch and fishing activities without any formal regulatory or legal incentives to do so. In theory, it is possible that voluntary self-reporting could provide a census of all catch; in practice, however, it is not realistic to assume that every fisher will devote the time and effort to provide complete data on every fishing trip they take. As a result, the number of fishing trips reported (the sample) relative to the total number of fishing trips that occurred (the population) is unknown. Further, the reported trips may not be an accurate representation of all trips, for example, if only the most experienced fishers voluntarily participate. These two factors together make voluntary self-reporting a non-probability sampling design, i.e., the probability of an individual sample unit (fishing trip) being sampled is unknown, therefore, estimating total catch is not possible. However, given strong enough incentives to participate and a planned sample design (for instance, a diversity of fishers are assigned to report all trips based on understanding of fisher skill, where they fish, etc.), self-reported data could theoretically be useful in fisheries stock assessment. We present here a summary description of voluntary self-reporting programs in Guam in the interest of completeness, but also in hopes that such programs might be developed further into probability-based self-reporting initiatives in the future.

9.1 Guam Fishermen's Co-op voluntary fishing trip survey

The Guam Fishermen's Co-op (the Co-op) administered a voluntary survey to member fishers to collect information on fishing activity and trip catch from 2004–2009. The objective of the survey was to better capture the portion of the catch that was not sold, because catch sold to the Co-op is recorded on commercial purchase invoices (Section 6). The survey was provided to fishers on paper forms. The boat and fishing activity survey was completed once by each fisher or boat, and contained questions such as boat name, launch/berthing site, boat length, frequency of fishing by method (troll, shallow bottomfish, deep bottomfish, etc.), and what portion of the catch is usually sold. The fishing trip survey contained questions regarding fishing effort (area, method, number of fishers, time fishing) and catch (species, number, and weight) for a single trip.

From 2004–2009, 1,056 total trips were reported (average 176 trips per year, range 91–330). Fewer than 3 fishers reported trips in several additional years and those data are excluded from these analyses to preserve confidentiality. Trolling accounted for 70% of total trips and bottomfishing accounted for 22% of total trips (Figure 9-1). Bottomfishing was split evenly between deep and shallow; however, more deep bottomfishing trips were reported earlier in the timeseries and shallow bottomfishing became more prevalent after 2008. There were 87 trips that reported using two or three different fishing methods (for example troll and bottomfishing). Trips with multiple fishing methods are counted in multiple method categories in Figure 9-1, e.g., the total number of "trips" shown is 1,128.

Fifty-three (53) fishers provided trip reports for bottomfishing from 2004–2009. Participation was greatest in 2004 when 22 fishers submitted trip reports, then declined to 10 in 2009 (Figure 9-2). The majority of bottomfishers who participating in the voluntary trip survey only submitted 1 trip report over the program's 6 years, with only 4 bottomfishers reporting 11 or more trips (Figure 9-3).

9.2 CatchIt LogIt application suite

The web-based CatchIt LogIt Application Suite for smart devices was developed by the WPFMC beginning in 2019. It includes electronic reporting forms for fishers and vendors to record information on their catch and purchases/sales such as species, weight, and trip-level information. CatchIt LogIt was initially released and promoted in Guam to fishers and vendors in late 2020. Use of the application for self-reporting catch and sales is voluntary in Guam where there are no mandatory catch reporting regulations. During the pilot implementation of the CatchIt LogIt program in 2021, the number of fishers reporting was highest in January (10 trolling fishers and 6 bottomfishers) and had decreased to approximately 5 fishers submitting reports per month by the end of the year (Sabater et al., 2022). Similar to the Guam Fishermen's Co-op Voluntary Fishing Trip Survey, the majority of fishers participating in CatchIt LogIt voluntary self-reporting only submitted a single report. Efforts to improve implementation of voluntary electronic self-reporting for fishers and vendors using the CatchIt LogIt application suite are ongoing. There are now mandatory license and reporting requirements for fishers and vendors in Guam, centralized data handling and warehousing, and increased accessibility of results reporting.

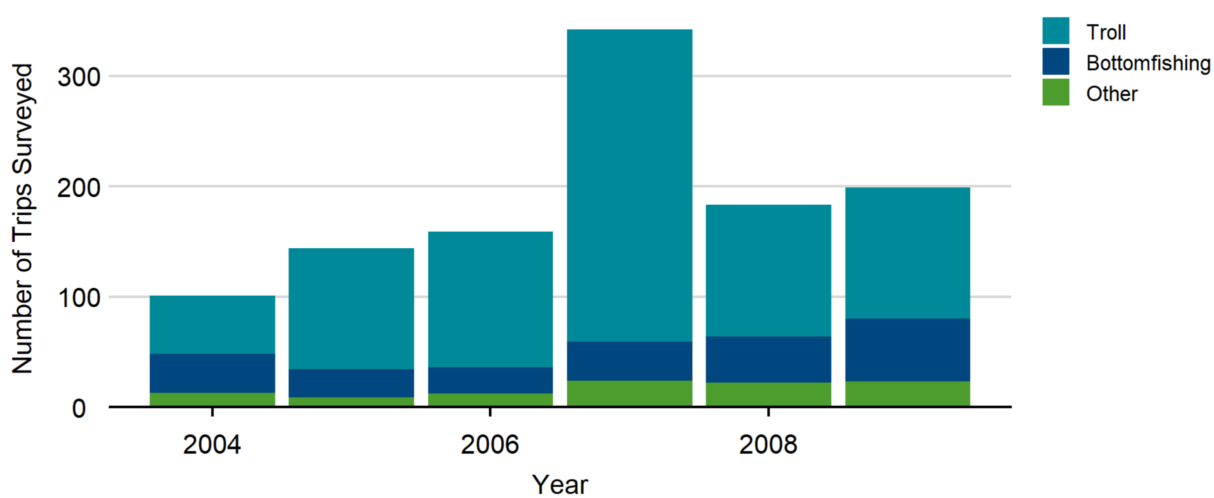


Figure 9-1. Number of trips reported annually by fishing method in the Guam Fishermen's Co-op Voluntary Fishing Trip Survey 2004–2009. Bottomfishing was reported as either shallow or deep, but is shown as a single method because fewer than 3 fishers reported shallow or deep in some years. 'Other' methods, in order of decreasing participation, included spear, unknown/'other,' jigging, and hook and line.

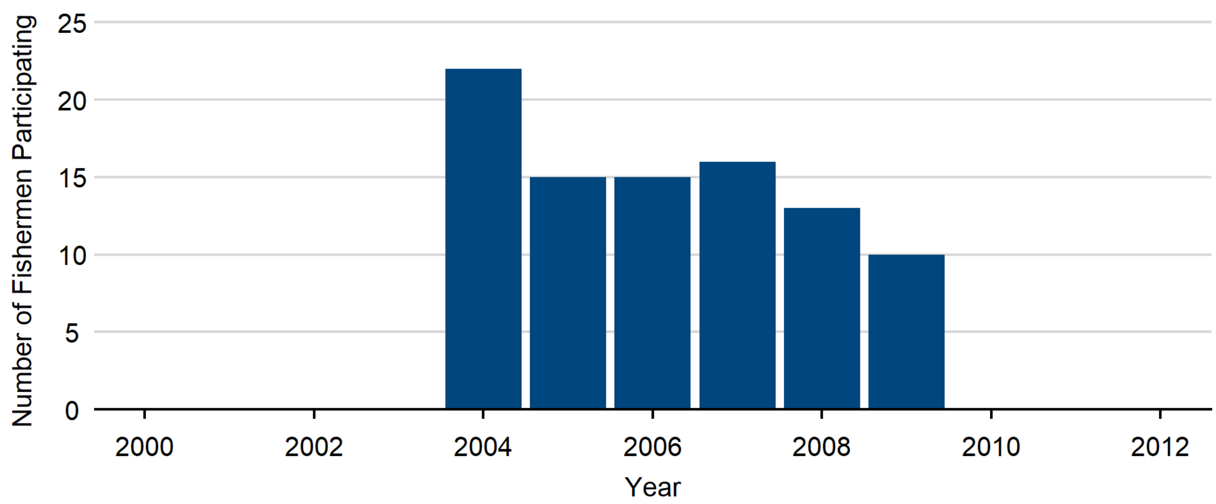


Figure 9-2. Number of fishers submitting trip survey reports annually for bottomfishing (shallow or deep) in the Guam Fishermen's Co-op Voluntary Fishing Trip Survey 2004–2009.

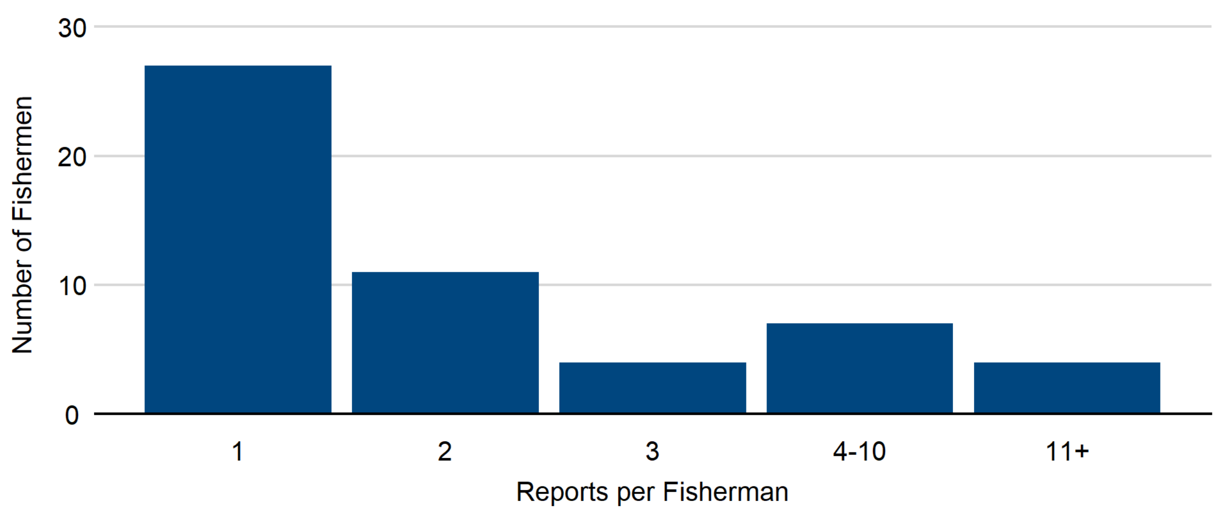


Figure 9-3. Number of trip survey reports for bottomfishing (shallow or deep) submitted by each fisher in the Guam Fishermen's Co-op Voluntary Fishing Trip Survey 2004–2009.

10. Discussion

The NOAA Fisheries Pacific Islands Fisheries Science Center (PIFSC) Stock Assessment Program has conducted regular assessments of the Guam bottomfish management unit species (BMUS) since 2007. The 2007 benchmark assessment first implemented a Bayesian surplus-production model which directly estimated maximum sustainable yield (MSY)-based reference points as well as biomass and fishing mortality trajectories (Moffitt et al., 2007). This surplus-production model used estimated annual landings and a nominal catch-per-unit-effort (CPUE) index from the Boat- and Shore-Based Creel Surveys. The 2007 benchmark assessment was updated with more recent data in 2012 and 2016 (Brodziak et al., 2012; Yau et al., 2016). In 2019, a new BMUS benchmark assessment was implemented also using a Bayesian surplus-production model but incorporating new software (JABBA), a standardized CPUE index from boat-based creel surveys, and an improved way of identifying BMUS-targeting fishing trips (Langseth et al., 2019). All these assessments were conducted at the BMUS-complex level, with no species-specific information.

Following the 2019 assessment, the PIFSC stock assessment program began exploring the data available in Guam to identify the next steps towards improving BMUS stock assessments. A primary improvement over previous assessments would be to split the BMUS complex into individual species. Moving to species-level assessments would be advantageous for many reasons, including: (1) increased flexibility and diversity of assessment modeling options available, and (2) enabled selection of the most appropriate assessment model for the amount and types of data available on a species-by-species basis. There are numerous stock assessment methods ranging from relatively simple to very complex modeling approaches. All assessment methods require one or more of the main data types: catch, size (length or weight), and CPUE (Figure 10-1). In addition, most approaches require information on life history such as growth (age-length relationship), maturity, fecundity, and recruitment. Statistical catch-at-age modeling approaches including integrated assessment techniques such as Stock Synthesis, are among the most data-demanding because they require catch, size (or age), CPUE, and life history data. Stock assessment approaches that rely on life history characteristics are typically only suited to apply to single species.

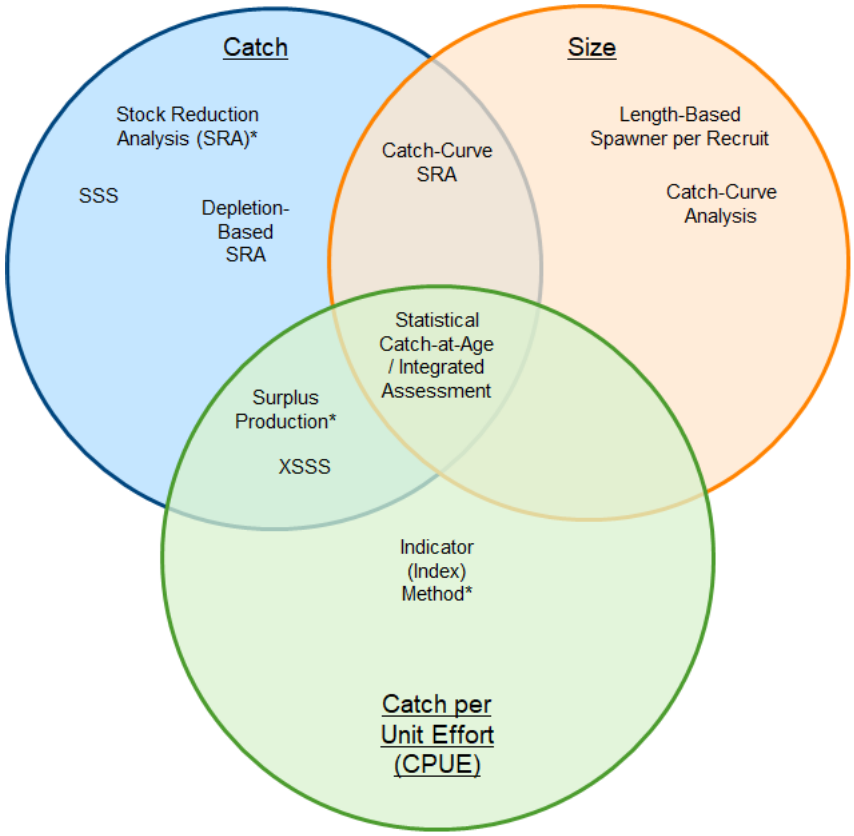


Figure 10-1. Data types required for several stock assessment approaches. Approaches noted with (*) can be used without life history information.

The objective of this report is to explore the different data sources in Guam for catch, size, and CPUE data to determine the types of assessment models that could be implemented in the next benchmark assessments. We evaluated five criteria to characterize the overall amount and quality of available data for each BMUS in Guam: (1) availability of historical (1967–1981) catch estimates, (2) variability and uncertainty in recent (1982–2021) catch estimates, (3) species occurrence in the most likely source of abundance indices (the Boat-Based Creel Survey, BBS), (4) number of individual size observations, and (5) relevance and dependability of life history studies. For each criterion, we defined values or qualitative characterizations to categorize the level of information or usefulness in the available data as either low (red), moderate (yellow), or high (green). The 5 criteria and the definition of the different levels (Table 10-1) are presented here as approximations only. The intent is to establish an initial impression of the level of confidence we have in being able to assemble catch, size data, CPUE, and life-history information that will enable new assessment approaches for the BMUS.

Table 10-1. Criteria used to evaluate overall usefulness (amount and quality) of catch, CPUE, and size data for each BMUS in Guam.

Criteria	Level of Information / Usefulness		
	High	Medium	Low
1) Historical landings Recorded at species level in surveys and landings reports 1967–1981.	Landings by species provided in literature	Identified to species in research / exploratory fishing surveys	No species-specific identification
2) Recent landings Variability of 1982–2021 species-identified BBS landings estimate. Group-identified catch contributes >10% of annual BBS landings estimate.	CV < 1 and N years < 10	CV ≥ 1 or N years ≥ 10	CV ≥ 1 and N years ≥ 10
3) Species occurrence Percent of total BBS interviews with species-specific records.	> 20	10–20	< 10
4) Individual size observations from the Biosampling Program Average measurements per year. Number years with > 50 measurements.	Average > 50 Years > 10	Average > 50 Years ≤ 10	Average ≤ 50 Years ≤ 10
5) Life-history studies Study location. Sample size. Sample max age observed percent of max age globally	Mariana Archipelago ≥ 100 ≥ 90%	Pacific Ocean ≥ 100 ≥ 40%	Pacific Ocean < 100 or < 40%

10.1 General observations

Many assessment modeling approaches require timeseries of catch estimates, commonly in terms of the weight of fish harvested or removed from the stock each year. The most valuable catch data are long timeseries with consistently low estimate uncertainty. It is ideal to have annual catch estimates going back to the beginning of a fishery, or at least a reliable understanding of fishing exploitation rate at the first year in the stock assessment model. Based on historical accounts, it is reasonable to assume that Guam BMUS, especially the deepest dwelling *Etelis* and *Pristipomoides* species, were essentially unfished in 1955 (e.g., fishing exploitation rate was zero and had been for many years; Section 7). There are no data available on BMUS catches between 1956 and 1966; hence, estimating catches 1956–1966 would require strong assumptions such as the catch being equal to zero or increasingly linearly to the 1967 catch. Aggregated catch of all bottomfishes is available beginning in 1967, but species-specific information is lacking for most BMUS. Given the absence of catch estimates from 1956–1966 and the uncertainty of catch estimates from 1967–1981, establishing complete and accurate catch histories of Guam BMUS will be challenging for all species.

Recent (1982–2021) catch estimates for most BMUS are more reliable; however, several species are inconsistently encountered in catch data sources such as the BBS. This is particularly the case for BMUS that may not be identified at the species level, so additional uncertainty in catch estimates is introduced by assumptions regarding the species composition of grouped catch estimates (e.g., jacks, snappers, bottomfish). Further, due to the design of the BBS and limited interviews in some years and expansion strata, annual catch estimates have high uncertainty, potentially obscuring underlying catch trends that would be informative in an assessment model.

Similar to catch estimates, CPUE information is most valuable for longer timeseries with less uncertainty. Data used to develop CPUE indices must include effort information (e.g., how long a fisher fished or how many gears were used) as well as any factors that might influence fish catch rates (e.g., time of day, area, or depth where fishing occurred). CPUE may come from fisheries-independent surveys but commonly come from fisheries-dependent data sources. Because there are no useable fisheries-independent data sources for Guam BMUS (Section 8), CPUE for stock assessments will likely come from the BBS. Unlike the SBS and the NOAA diver surveys, the BBS includes many records of BMUS and also constitutes a relative long timeseries (approximately 40 years of data). Of the 13 BMUS, 8 species are encountered in less than 10% of BBS interviews, which makes estimating CPUE challenging because the sample size of interviews that did include a record of that species may be small or zero in some years.

There are no size (individual length or weight) data for BMUS before 1982, except for some isolated observations from miscellaneous surveys and reports that constitute too small or non-representative sample to be useful. Field survey protocols for the BBS instruct interviewers to record individual fish lengths or weights; however, direction regarding the number of individuals per species that should be measured have changed over the timeseries of the BBS. Specific guidance is vague or contradictory on which individuals of a species should be selected for measurement. Given non-random subsampling of fish lengths within each interview, BBS length data must be filtered to include only interviews where every individual of a BMUS was measured. The resulting small sample sizes, averaging less than 20 lengths per year for 12 of the 13 BMUS, likely preclude the use of BBS length data in a stock assessment. The biosampling field data set, although the timeseries is limited to only 12 years, is the most likely source of size data for BMUS assessments. The number of fish measured per year in the biosampling data is limited and highly variable for most BMUS and only two species (*L. rubrioperculatus* and *P. auricilla*) had sufficiently large sample sizes to potentially enable statistical catch (length)-at-age stock assessment approaches such as Stock Synthesis.

Life history data related to growth, maturity, and longevity are available for all 13 Guam BMUS in the Mariana Archipelago. Most of these local life history studies relied on small sample sizes (ranging from 17 to 62 individuals) or did not include older fish, increasing the probability that resultant age-growth parameters may be greatly over or under estimated relative to the true biology of the fish. The Life History Program at PIFSC is continuously working to analyze specimens from the biosampling lab data set and research surveys and should improve estimates of growth, maturity, and mortality parameters of BMUS lacking recent or local studies for inclusion in the 2024 stock assessments.

In addition to the general trends of limited and uncertain catch estimates, uncommon occurrence of BMUS in the available data sources, and paucity of length information, there are several species-specific observations on data availability or usefulness that might impact the ability to conduct advanced stock assessments.

10.2 Species-specific observations

We believe there are sufficient data available to perform some variation of single-species stock assessments on most of the 13 BMUS in Guam. However, our confidence in being able to estimate catch, CPUE, size compositions, and life history parameters, as judged by our five criteria for the amount and quality of available data, varies among species (Table 8-2). In this section, we summarize the data challenges and strengths for each BMUS separately.

Table 10-2. Summary of the data available for 13 BMUS in Guam. Criteria definitions and corresponding colors are detailed in Table 10-1.

BMUS	Criteria				
	1) Historical Landings Recorded at species level	**2) Recent Landings** CV over years | years with group-identified > 10% total	**3) Species Occurrence** % BBS interviews	**4) Size Observations** Average per year | years with > 50 samples	**5) Life History** Location | sample size | A_{max} % global
Aphareus rutilans	Yes	0.95 | 7	6.1	20 | 1	Mariana | 26 | 44
Caranx ignobilis	No	1.9 | 16	1.9	11 | 0	MHI | 180 | 100
Caranx lugubris	Yes	1.25 | 6	3.8	24 | 2	Mariana | 25 | 100
Etelis carbunculus	Yes	0.86 | 5	9.3	70 | 7	Mariana | 62 | 7
Etelis coruscans	Yes	1.39 | 10	5.6	42 | 4	Okinawa | 768 | 100
Lethrinus rubrioperculatus	No	0.83 | 13	24.4	590 | 11	Mariana | 275 | 100
Lutjanus kasmira	No	0.65 | 13	13.3	99 | 8	Mariana | 33 | 100
Pristipomoides auricilla	Yes	0.79 | 5	12.6	277 | 12	Mariana | 295 | 100
Pristipomoides filamentosus	Yes	1.06 | 5	3.4	21 | 2	Mariana | 217 | 47
Pristipomoides flavipinnis	Yes	1.06 | 5	5.8	51 | 5	Mariana | 57 | 21
Pristipomoides sieboldii	No	2.48 | 13	0.8	31 | 2	Okinawa | 371 | 100
Pristipomoides zonatus	Yes	0.76 | 3	11.9	73 | 8	Guam | 317 | 100
Variola louti	No	0.99 | 4	10.2	88 | 7	Guam | 287 | 93

10.2.1 Aphareus rutilans

Catch estimates for *A. rutilans* range from 37 to 2,438 kg annually, with relatively low variability over recent years. This species was also noted in several fisheries investigations before 1982. However, *A. rutilans* is recorded in only 6.1% of BBS interviews; hence, estimating a standardized CPUE timeseries for this species will be challenging. Size observations are also very limited, with an average of 20 individuals per year from the biosampling data, 2009–2021. Given CPUE and size data are not highly available for *A. rutilans*, it is likely that assessment methods for this species will rely on catch and possibly life history information.

10.2.2 *Caranx ignobilis*

Catch estimates of *C. ignobilis* are highly variable, ranging from less than 10 kg in 1982 to 6,525 kg in 2013. This is the most frequently identified BMUS in the SBS, with annual expanded landings from shore-based gears exceeding 1,000 kg in several years and representing upwards of 1.8% of total shore-based landings. Smaller *C. ignobilis* are occasionally taken by shore-based fishers using gillnet and hook-and-line gear. According to fishers' accounts, larger individuals are generally only targeted by sportfishers. Although non-sport fishers may keep smaller individuals that are caught incidentally while shallow bottomfishing, the larger fish are unappealing because they often have flesh parasites and may be ciguatoxic (Iwane et al., 2023). Accordingly, *C. ignobili*s are rare in the BBS interview data, and generation of a standardized CPUE index for identified adults of this species is unlikely. Finally, the biosampling field data set included, on average, 11 lengths of *C. ignobilis* per year from bottomfishing, with no years having more than 50 individuals measured. Biosampling lengths from spearfishing and net gears are more numerous; however, they may be of limited utility without making strong assumptions regarding fisher behavior and gear selectivity in order to combine length information from one part of the fishery to catch information from another. Given high uncertainty in recent annual landings estimates, a prospective lack of standardized CPUE timeseries, and unavailability of length data from bottomfishing, producing a stock assessment for this BMUS will be very challenging, and will likely rely on data-limited methods.

10.2.3 *Caranx lugubris*

Generally, *C. lugubris* is described by the same paucity of catch, CPUE, size, and life history information as *C. ignobilis*, even though the former is considered a more appealing food fish. This species is relatively rare in the BBS interview data, therefore, estimated annual catches are highly variable. For example, annual catch in recent years (2017–2021) averaged nearly 1,300 kg per year, but ranged from over 4,500 kg in 2019 to 115 kg in 2020. There are some length observations available from the biosampling field data set; however, the majority of 293 length observations were from just two years: 2017 (135 fish measured) and 2019 (74 fish measured). Although length data are not sufficient for a timeseries analysis, aggregated sample size over the past several years may be adequate to allow for a data-limited, length-based assessment approach for this BMUS.

10.2.4 *Etelis carbunculus*

Timeseries catch estimates and CPUE of *E. carbunculus* are highly unreliable due to a newly-reported species that was likely previously misidentified as *E. carbunculus*. This new species, the giant ruby snapper (*Etelis boweni*), is very similar in appearance to *E. carbunculus* but reaches greater lengths (maximum lengths around 115 cm vs. 47 cm, respectively; Andrews et al., 2021). Accounts of fishers, DAWR staff, and NOAA Fisheries scientists confirm *E. boweni* are present in Guam (Iwane et al., 2023; Dahl et al., 2024) despite not being reported in the BBS data. Length observations of *E. carbunculus* from the biosampling field data set for the past several years (i.e., after technicians were trained in differentiating *E. carbunculus* from *E. boweni*) may be useable for a simplified data-limited, length-only stock assessment. Otherwise, due to these data limitations, it may not be possible to perform any stock assessment of *E. carbunculus* at this time.

10.2.5 Etelis coruscans

Estimated annual *E. coruscans* catch averaged 2,500 kg from 1982–2021. Catch was small in some years (e.g., less than 200 kg per year in each 2013 and 2014), yet the largest estimated annual catch was over 17,000 kg in 2021. Several Guam fishers have confirmed their experiences that catches of *E. coruscans* are highly variable between years. They also suggested bottomfishing in deep waters where *Etelis* and *Pristipomoides* species occur has increased in popularity over the past several years (Iwane et al., 2023). Overall, *E. coruscans* was observed in 5.6% of BBS interviews; however, the species is very rare in some years which will likely hinder efforts to produce a standardized CPUE timeseries. Length observations of *E. coruscans* are limited and inconsistent, from both the biosampling field data set (average 42, range 10–101 observations per year) and the BBS (average 7, range 0–25 observations per year from complete interviews only). Although length data are not sufficient for a timeseries analysis, aggregated sample size over the past several years may be adequate to allow for a data-limited, length-based assessment approach for this BMUS. Such an assessment would require dependable life history parameter estimates, which may be available from a recently completed large sample size life history study of *E. coruscans* from the Okinawa Islands in Japan (Uehara, 2020).

10.2.6 Lethrinus rubrioperculatus

Of the Guam BMUS, *L. rubrioperculatus* is one of the species for which the most data are available. It had the highest estimated landings of all BMUS (average 5,350, range 210–17,000 kg per year) and was also the most frequently encountered BMUS in BBS interviews (occurring in 24.4% of interviews). Consistent recent landings and high occurrence in the BBS interview data indicate the generation of a standardized CPUE index may be possible. However, several years with large group-identified catches, particularly “shallow bottomfishes,” which peaked at 5,900 kg in 1997, may contribute uncertainty in annual catch estimates and a standardized CPUE timeseries. There are historical accounts of *L. rubrioperculatus* that may be sufficient to estimate pre-1982 landings (and hence generate a complete catch history). *L. rubrioperculatus* life history is also well understood from an extensive study from the Northern Mariana Islands (Trianni, 2011). Notably, this BMUS has a large number of length observations; there were an average 590 (range 1–1857) per year in the biosampling field data set from 2010–2021. There was also an average 40 length observations (range 3–139) per year collected from complete BBS interviews (i.e., every *L. rubrioperculatus* in the catch was measured) from 1982–2021. Availability of the large number of length observations, including some observations in the earliest years of the BBS, improves the prospects of applying a more complex statistical catch-at-age assessment model for this BMUS.

10.2.7 Lutjanus kasmira

Estimated annual *L. kasmira* catch averaged 830 kg, with relatively low interannual variability, from 1982–2021. However, 13 years with large group-identified catches (particularly "shallow bottomfishes," which peaked at 5,900 kg in 1997) contributed greater than 10% of annual estimated *L. kasmira* catch. This added uncertainty in estimated catch, which also affects potential CPUE standardization, may prove challenging in a stock assessment. There are an average of 99 length observations per year of *L. kasmira* from the biosampling field data set, but length observations have been more limited in recent years. The only life history study based on *L. kasmira* caught from the Mariana Islands was in the 1980s using a sample size of 33 (Ralston and Williams, 1988). Finally, early catches (pre-1982) of *L. kasmira* may be difficult to estimate because despite generally occurring in shallower water closer to shore, allowing easy accessibility to the early bottomfish fishery, this BMUS was not specifically identified in historical data. Considering potential higher uncertainty than other BMUS in catches and CPUE, only a moderate amount of length observations, and a small-sample size life history study, a statistical catch-at-age stock assessment of *L. kasmira* is unlikely. Instead, any assessment may need to depend heavily on length-based methods and ideally include more comprehensive estimates of life history parameters.

10.2.8 Pristipomoides auricilla

There were an average of 277 (range 1–685) *P. auricilla* length observations per year from the biosampling field data set from 2009–2021. The PIFSC Life History Program has also recently published a large-sample life history study for *P. auricilla* based on specimens collected from the Guam Biosampling Program (O'Malley et al., 2019). According to accounts from Guam fishers, this BMUS has become more common in bottomfishing catches in recent years which is supported by a positive trend in estimated landings of *P. auricilla* (increasing from 690 kg in 2017 to 7,500 kg in 2021). Over all years of the BBS, *P. auricilla* was encountered in 12.6% of interviews. The combination of available length observations, well-established life history information, potential standardized CPUE index, and consistent catches in recent years suggests several options, including statistical catch-at-age models, could potentially be applied to this BMUS.

10.2.9 Pristipomoides filamentosus

P. filamentosus is rarely recorded in the BBS (3.4% of bottomfishing interviews, 1982–2021). *P. filamentosus* was somewhat more common in the 1980s, occurring in over 10% of all bottomfishing interviews in 1984. Estimated annual landings are among the lowest of the BMUS, averaging less than 325 kg (range 0–1,532 kg). Discussions with the Guam DAWR indicate a similar-appearing species, *P. sieboldii*, may have been misidentified as *P. filamentosus* over the majority of the BBS timeseries (Iwane et al., 2023), which could reduce the dependability of catch estimates and CPUE timeseries for *P. filamentosus*. Length observations from the biosampling field data set are limited, averaging 21 per year. The relative rarity of this BMUS in the BBS data, potential species identification problems, and few length observations suggest applicable assessment approaches for this stock may be limited.

10.2.10 Pristipomoides flavipinnis

Estimated annual *P. flavipinnis* catch averaged 620 kg from 1982–2021, and this species was noted in several fisheries investigations before 1982. However, *P. flavipinnis* is recorded in only 5.8% of BBS interviews; therefore, estimating a CPUE timeseries for this species may be challenging. There was an average of 51 length observations per year from the biosampling field data set 2009–2021, which may be sufficient for a length-based assessment. Life history studies are lacking for this BMUS; the only study conducted on *P. flavipinnis* caught from the Mariana Islands was in the 1980s and was based on young fish only, relative to larger sample-size life history studies in other regions (Ralston and Williams, 1988; O'Malley et al., 2019). Considering this BMUS' relative rarity of occurrence in the BBS, moderate length observations, and limited understanding of this species' life history in the Mariana Archipelago, a statistical catch-at-age stock assessment of *P. flavipinnis* is unlikely. Instead, any assessment may need to depend heavily on length-based methods and ideally include updated studies with more comprehensive estimates of life history parameters.

10.2.11 Pristipomoides sieboldii

P. sieboldii is rarely recorded in the BBS (0.8% of bottomfishing interviews, 1982–2021) and was absent in 18 of the 40 years of the survey. Estimated annual landings are low, averaging less than 100 kg (range 0–1,200 kg). The only life history study based on *P. sieboldii* caught in the Mariana Archipelago was in the 1980s and depended on a sample size of 8 (Ralston and Williams, 1988). Length observations are scarce, from both the biosampling field data set (average 31 observations per year) and the BBS (average 3.4 observations per year from complete interviews). *P. sieboldii* was somewhat more common in the 1980s, occurring in over 4% of all bottomfishing interviews in 1982. Discussions with the Guam DAWR indicate this species may have been misidentified as *P. filamentosus* over the early years of the BBS timeseries, which could explain the apparent rarity of this species and also increases uncertainty around catch estimates. Recent records of *P. sieboldii* may be more reliable, because DAWR personnel were more confident in correct identification of *P. sieboldii* since coordination with NOAA Fisheries scientists in 2014 (Iwane et al., 2023). The overall paucity of data on this BMUS suggests implementing any stock assessment approach may not be possible at this time.

10.2.12 Pristipomoides zonatus

Catch estimates for *P. zonatus* averaged 1,360 kg per year (range 82 to 4,260 kg), with relatively low variability over recent years. This BMUS has a distinctive appearance and was noted in several fisheries investigations before 1982. There was an average of 73 *P. zonatus* length observations per year from the biosampling field data set from 2009–2021, with most years having more than 50 length observations. Over all years of the BBS, *P. zonatus* was encountered in 11.9% of interviews. The PIFSC Life History Program has also recently published a comprehensive life history study for *P. zonatus*, including maturity and sex-specific growth, based on specimens collected from Guam (Schemmel et al., 2022). The combination of consistent catches in recent years, available length observations, a potential standardized CPUE timeseries, and well-established life history information suggests a range of stock assessment approaches, including statistical catch-at-age models, could potentially be applied to this BMUS.

10.2.13 Variola louti

V. louti is unique among the BMUS because a large amount of surveyed catch and landings are estimated from spearfishing, especially during the 1990s and early 2000s. Total annual landings peaked at 3,160 kg in 2003, and averaged 688 kg per year 1982–2021. *V. louti* are somewhat frequently encountered by bottomfishers, occurring in 10.2% of BBS interviews. However, the formulation of a standardized CPUE timeseries for *V. louti* from spearfishing may be challenging because *V. louti* occur in only 4.8% of spearfishing interviews over the timeseries. Further, spearfishers as a group may be further divided among dissimilar free-diving and SCUBA methods, and spearfishers operating from the shore are rarely observed relative to other gear types (Jasper et al., 2016). Length observations from the biosampling field data set are predominantly from spearfishing and relatively few length observations have been collected from either gear in recent years (average 32 length observations per year for 2017–2021, spearfishing and bottomfishing combined). The overall low occurrence in survey interviews and size observations, combined with the influence of two different fishing methods (spearfishing and bottomfishing) contributing to the data suggest more advanced age-structured assessment models will be challenging. Growth, maturity, and natural mortality estimates are available from a recent life history study of *V. louti* in Guam (Schemmel and Dahl, 2023) which, together with aggregated length observations from the past several years, may be sufficient to allow for a data-limited, length-based assessment approach for this BMUS.

10.3 Conclusions

The goal of this report was to compile and evaluate all potential data sources for the next generation of BMUS stock assessments in Guam. One important step in improving these assessments would be to move from complex- to species-level population assessment models. This would enable the use of length (age)-based modeling options that incorporate size and life history information to minimize uncertainty in assessment results and produce higher quality management advice. Overall, we found perhaps only two of the 13 Guam BMUS (*L. rubrioperculatus* and *P. auricilla*) have sufficient data to run integrated or length-based assessment models, owing primarily to the paucity of length measurements. There are likely not enough data to run any assessment models for *P. sieboldii* as they are rarely recorded in data sources that capture other BMUS, possibly due to misidentification of this species or its genuine rarity in Guam. Co-occurrence of a newly described cryptic species (*E. boweni*) to *E. carbunculus* may preclude any stock assessment of this species. Performing stock assessments of the remaining eight Guam BMUS may require drawing on a range of stock assessment modeling approaches, including catch-only methods, length-based spawner per recruit analysis, and surplus production modeling.

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