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Comparing Data-Poor and Data-Rich Stock Assessments to Generalise Guidance for Pacific Coral-Reef Fisheries

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ABSTRACT

The growing use of data-poor fisheries models provides unprecedented access to compelling stock metrics and management scenarios for coral-reef fisheries. Yet, it remains unclear how well the assumptions surrounding data-poor models derived from extensive cold-water fisheries fit the life histories and ecology of tropical coral-reef fishes. The present study compared the outcomes from length-based spawning potential ratio (LBSPR) models versus observed trends from a novel meta-analysis of nine fisheries-independent (FI) and fisheries-dependent (FD) data streams across Micronesia. Thirty target species that comprised over 70% of landings were examined across temporal and spatial fishing pressure gradients associated with FI and FD streams. Cluster analyses using normalised effect sizes from over 140 statistical tests grouped the stocks based on the magnitudes of decline in (proportional) biomass and size-structure. Interestingly, many species with the greatest declines had modelled SPR and fishing mortality outcomes that did not trigger management based on established thresholds. These inconsistencies were attributed to several factors: variable compensatory density dependence across species, rapid growth over short time periods for small-bodied species leading to hyper-sensitive switch points in SPR metrics, and unusually long lifespans that did not always correlate with body sizes or growth rates. The complexity of life histories appeared to limit the use of snapshot data-poor models for depicting relative stock status across species; however, data-poor outcomes through time for each species better aligned with FI and FD trends. We generalise management guidance for a common and dominant group of tropical Pacific species.

1 | Introduction

Coral-reef fisheries across the Pacific are difficult to manage because they are spread across many independent island nations with over 100 target species that are ecologically isolated from each other. High diversity and isolation make long-term fisheries-dependent (FD) and fisheries-independent (FI) data streams expensive compared to stock values, leading to data-poor situations (Dowling et al. 2015; Hordyk, Loneragan, et al. 2015; Froese et al. 2018). In contrast, temperate and cold-water fisheries often have extensive stock sizes associated with individual states or countries that can be worth millions, up to a billion United States Dollars per year in the case of the Alaska pollock (Bailey 2021). Unsurprisingly, cold-water fisheries have

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provided the basis for many models that have been extended to tropical coral-reef settings.

One key assumption of most fisheries models is that compensatory density dependence is the primary response of any fished stock, or that the removal of larger-and-older individuals will be compensated by faster replenishment of smaller-and-younger counterparts until a maximum biomass turnover, or maximum sustainable yield (MSY), can emerge (Beverton and Holt 1957; Walters 1969; Pauly and Froese 2021). This concept is rooted in longstanding theory that scales metabolic rates with body sizes (Brown et al. 2004; Burger et al. 2019), and extends allometric scaling patterns to population growth rates and carrying capacities. While these assumptions have proven useful for extensive single-species stocks in cold waters, the consequences of applying these assumptions to diverse, multispecies coral-reef fisheries are poorly understood.

Recent studies have revealed strikingly different compensatory density dependence for similar-sized species within the same trophic guilds and families that dominate coral-reef fisheries landings across many Micronesia islands (Houk et al. 2017, 2018a, 2021). The Pacific longnose parrotfish, *Hipposcarus longiceps*, had significant size-truncation while remaining dominant in FD and FI data, while the steephead parrotfish, *Chlorurus microrhinos*, had limited size-truncation and slowly disappeared from reefs and landings. Similar differences were also revealed for common snappers and emperorfishes that dominated landings, and the presence or absence of compensatory density dependence was predicted by phylogenies representing the evolutionary genetic distances between species (Houk et al. 2021). Beyond population replenishment rates, large differences in natural mortality have recently been revealed between two dominant families of herbivores/detritivores, the surgeonfishes and parrotfishes, that had limited affinity with body size (Taylor, Prince, et al. 2024). Therefore, it appears that some species attributes and life-history traits may not necessarily scale with body size but instead be ingrained in species identity.

The present study investigated how diverse life histories might influence the outcomes of data-poor fisheries models. This is timely because two data-poor models are increasingly being applied to single or combined stocks within diverse coral-reef fisheries. Catch-MSY models iteratively select intrinsic population growth rates and carrying capacities to simulate stock biomasses that best correspond with catch time-series data given realistic levels of fishing mortality (Froese et al. 2017). Variations of these models use biomass instead of catch for both multispecies MSY targets (McClanahan et al. 2015; McClanahan 2018) and MSY targets derived for groups or guilds of species with similar ecology and life history (Houk et al. 2018b). While the outcomes provided stock biomass estimates to set overall catch limits, they offered limited guidance to determine what management strategies were best suited for each target species to help meet these limits (i.e., size, gear, or overall effort).

In contrast, a second class of fisheries models are based upon species life-history parameters that can forecast size and age structures of unfished populations (Levin and Goodyear 1980; Schnute 1987; Frøysa et al. 2002; Hordyk, Ono, et al. 2015). Unfished population structures are contrasted with representative catch data to determine how much size and age truncation may exist, and the outcomes are translated into numerous benchmarks such as yield-per-recruit, fishing-versus-natural mortality, and spawning potential ratios (SPR). These outcomes are compelling because managers can forecast improvements by simulating changes in several parameters such as size-at-capture or overall fishing effort. The rise in these data-poor models is exemplified by Google Scholar searches for peer-reviewed studies and grey-literature using the keywords "spawning potential ratio coral-reef fish" in the title or abstract. The results showcase a significant increase from 50 publications in 2000 to 331 in 2023, with exponential growth after an informative and freely available R package was developed, followed by the creation of several online tools for fisheries managers (www.fisheriestoolkit.org), (Hordyk, Ono et al. 2015; Hordyk 2022).

Given the growing reliance on data-poor approaches, the present study introduced a unique data-rich coral-reef fishery setting across Micronesia that was used to ground truth the outcomes of data-poor modelling and advance generalised guidance for the tropical Pacific. We synthesised nine unique sources of FI and FD data across space and time to assess how 30 target species may have responded to gradients of fishing pressure. The results offered a consensus-based assessment for each target species that predicted both status and what type(s) of management may be most relevant. Subsequent comparisons with snapshot and temporal LBSPR outcomes revealed strengths and weaknesses in terms of predicting stock status and management recommendations. Ultimately, our study simplified guidance for improving stock assessments and management approaches for diverse coral-reef fisheries across the Pacific.

2 | Methods

The present study was conducted across Micronesia, tropical Western Pacific Ocean, with a focus on the population center of Guam where the disproportionately largest number of humans per reef area exists (1435 people per km^2 of reef down to 30 m in depth) (Figure 1). Fisheries across this region provide for subsistence livelihoods, small-scale commercial industries, tourism, and encompass a wealth of cultural and traditional practices and knowledge. Several past studies have quantified fishing pressure gradients (i) across reefs within the main populated islands and (ii) across islands within the region (Houk et al. 2012, 2017; Taylor et al. 2014; Cuetos-Bueno et al. 2018). In addition, several studies have quantified temporal fishing pressure gradients in a few of the islands where extensive time-series data existed, including the focal island of Guam (Houk et al. 2018a; Rhodes et al. 2018; Cuetos-Bueno et al. 2019; Taylor et al. 2022). Spearfishing mainly at night with a flashlight and bottom fishing from both shore and boats are the two primary fisheries sectors in terms of participation and landings, with notable but relatively low contributions coming from other sectors such as net fishing. Both FD and FI monitoring have been ongoing across Micronesia over the past decade, with some islands having extensive spatial and temporal data from many independent sources. Guam in particular is a data-rich setting due to both local and federal (FD/FI) monitoring programs, many independent research projects conducted in collaboration with the

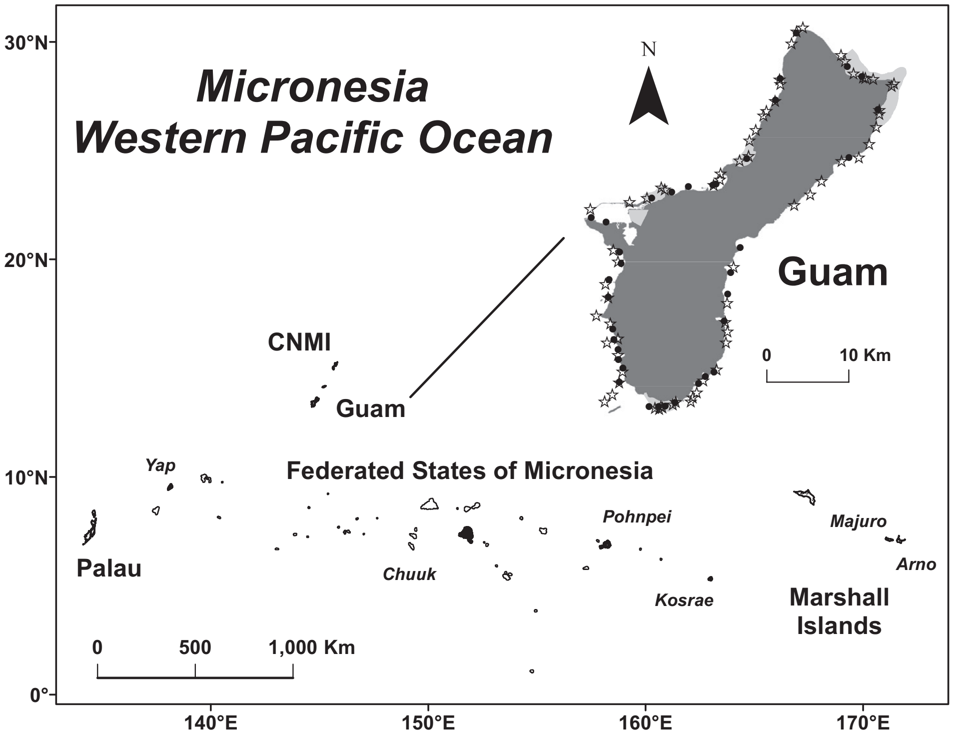

FIGURE 1 | Map of the western Pacific Ocean highlighting the Micronesia islands where fisheries data were collected. The inset map shows the focal island of Guam with representative sampling locations associated with two example data sources (Guam R2R, black circles; NOAA-NCRMP, stars, Section 2 for descriptions). No-take marine protected areas are shown in light grey polygons.

University of Guam Marine Laboratory, and extensive, locally-derived life-history information for many target coral-reef fishes. Given data streams and the growing reliance on coral-reef fisheries for both subsistence and economic needs, formal fisheries management planning (FMP) processes are growing across the region. One key component of FMP efforts is to generate scientific knowledge surrounding both the stock status and the best approaches towards managing each stock, forming the basis for the present study.

2.1 | Target Species

Target species were determined collaboratively by the authors, governmental agencies, and stakeholders based on: (1) dominance in landings and reef data, both past and present, (2) local knowledge regarding historical exploitation and desirability via fisher social media surveys, and (3) a desire to include representative species across both freedive spearfishing and bottom fishing sectors that contributed most to landings and are currently legal. Target species included several snappers (Lutjanidae), emperorfishes (Lethrinidae), parrotfishes (Labridae: Scarinae), groupers (Epinephelidae), surgeonfishes (Acanthuridae), rabbitfishes (Siganidae), one rudderfish (Kyphosidae), one goatfish (Mullidae), and one trevally (Carangidae) (Figure 2). Target species also included two iconic large-bodied species known to be sensitive to exploitation, *Bolbometopon muricatum* (bump-head parrotfish) and *Cheilinus undulatus* (Napoleon wrasse); however, data were insufficient to further their investigation. Together, the target species selected accounted for over 70% of the biomass in most datasets described below.

2.2 | Data Sources

FD and FI datasets that might contribute towards population assessments for target coral-reef fishes were identified from published studies, grey-literature such as student theses and technical reports, and unpublished data from monitoring efforts by local and federal programmes. One notable data source was absent: the National Oceanic and Atmospheric Administration Pacific Islands Fisheries Science Center bio-sampling programme did not release data due to privacy concerns. Data were reviewed for structure, format, and quality-control concerns such as taxonomy and minimum-maximum sizes recorded. Detailed summaries of each data source were previously published describing the survey protocols and nature of the fishing pressure gradients investigated (Houk and Taylor 2023). Therefore, shortened summaries are provided below followed by analytical approaches. Cumulatively, this process resulted in (nine) unique sources of data with sufficient coverage around Guam and Micronesia to evaluate a suite of defined target species.

2.2.1 | Guam Division of Aquatic and Wildlife Resources Creel (G-DAWR Creel)

G-DAWR established a FD monitoring program in the late 1980's that is based upon both commercial and recreational fisher intercepts around Guam. Creel surveys followed a regular annual-and-weekly schedule that included both day and night-time, weekdays and weekends. During each survey event, fish were identified and measured to the nearest millimetre (mm) fork length, and a series of standard questions were asked to

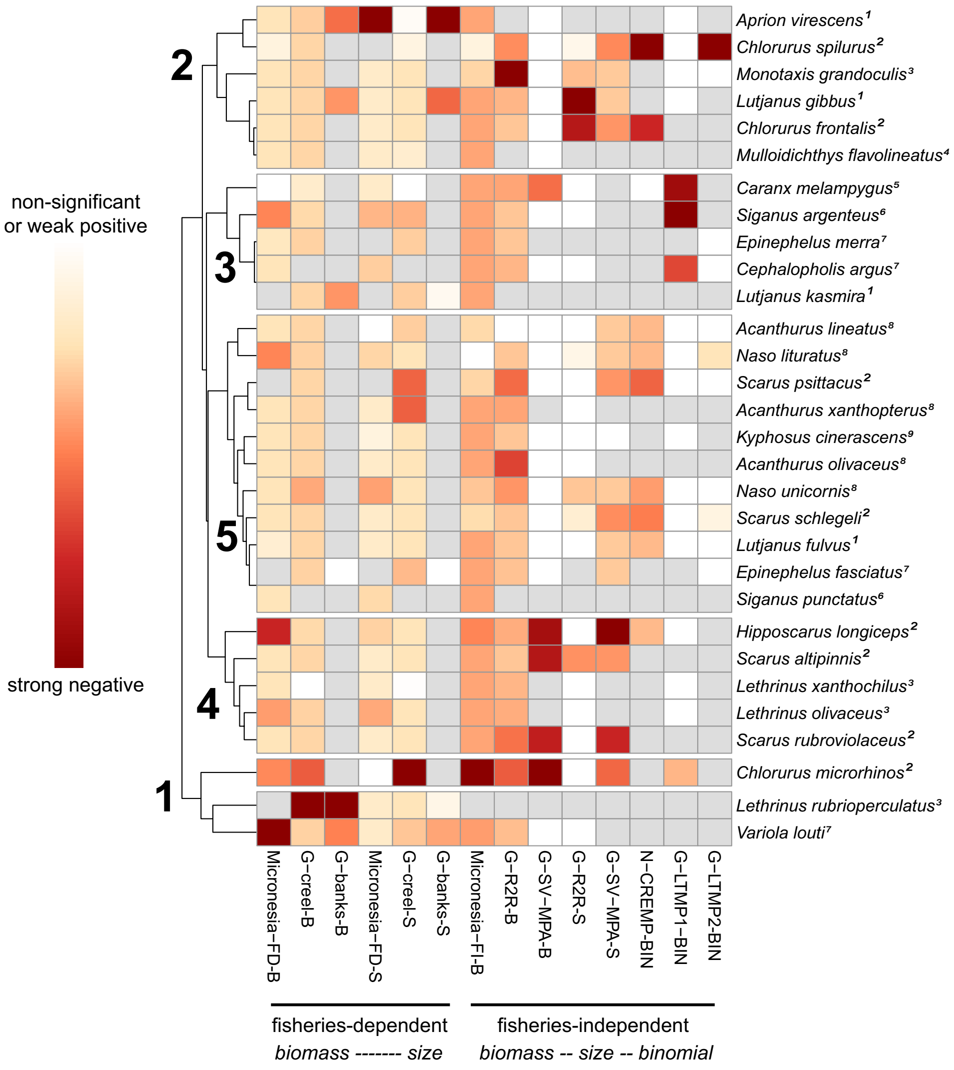

FIGURE 2 | Heatmap visualising the effect sizes of statistical tests for each species-dataset (see Appendix S2 for raw values associated with the heatmap). Target species were clustered into 5 groups based upon the effect sizes describing the strength of their responses to fishing pressure gradients (Section 2 for dataset descriptions and fishing pressure gradients examined). Data sources on the *x*-axis were organised from left to right based upon fisheries-dependent versus fisheries-independent, then organised based upon size (*S*) or biomass (*B*) examinations within each. Grey colours indicate that insufficient data were available to perform tests; the gradient of white to dark red colours scales with the magnitude of standardised effect sizes. Numbers after species indicate their respective families: ^{1}snappers (Lutjanidae), ^{2}parrotfishes (Labridae: Scarinae), ^{3}emperorfishes (Lethrinidae), ^{4}goatfish (Mullidae), ^{5}trevally (Carangidae), ^{6}rabbitfishes (Siganidae), ^{7}groupers (Epinephelidae), ^{8}surgeonfishes (Acanthuridae) and ^{9}rudderfish (Kyphosidae).

determine fishing location(s) and method(s). Trends in size-structure and proportional biomass were derived from these data as described above and in previous studies (Weijerman et al. 2016; Houk et al. 2018a).

2.2.2 | Guam Division of Aquatic and Wildlife Resources (G-DAWR) Bank Fishing

G-DAWR conducted a series of bottom fishing survey trips to three remote banks that varied in distance from Guam in the fall of 1998 and spring of 1999. In each instance, standardised fishing was conducted by bottom fishers placed in differing boat positions randomly. All fish landed were measured and weighed. Biomass and size data were aggregated to the bank-day level, then examined across banks following methods noted above. Distance from Guam was considered akin to accessibility and therefore fishing pressure.

2.2.3 | Guam Ridge-To-Reef (G-R2R)

Coral, benthic and fish assemblage data were collected on reefs adjacent to 35 Guam watersheds between 2020 and 2022 associated with the G-R2R program (Houk et al. 2022). Five 50 m transects were laid along the 8–10 m reef slope contour, and field protocols followed previous studies designed to meet statistical power needs for site-level resolution (Houk and Van Woesik 2013; Houk et al. 2015). Food-fish assemblages were estimated from 12 stationary-point counts (SPC) conducted at ~20 m intervals. During each SPC, the trained observer recorded the species name and the size of all food-fish within a 5–6 m radius for a period of 3 min. Comparisons of biomass and size were made with respect to MPA status, which was nested in geography.

2.2.4 | NOAA National Coral-Reef Monitoring Program (NCRMP)

NOAA Pacific Islands Ecosystem Sciences Division conducts a national coral-reef monitoring program for Pacific Islands and territories associated with the United States. Between 30 to 100 sites were established around Guam each year (2011, 2014 and 2017), across major habitat strata and three depth strata (Williams et al. 2012). SPC survey protocols involved a pair of divers conducting simultaneous counts in adjacent 15 m diameter cylinders ($n = 2$ counts per site). Divers spent the first 5 min recording the taxa observed within their cylinder. At the end of the 5 min period, divers systematically worked through their species list and recorded the number and size of fish. In cases where a species was observed during the first 5 min but was not present in the cylinder during the counting period, divers recorded their best estimates of size and numbers. The present study aggregated biomass and size data to the site level, then aggregated across the island to produce annual means for each target species. Data were analysed across years using pairwise binomial testing due to limited observations of many target species at any given site (i.e., zero-inflated).

2.2.5 | Guam Long-Term Monitoring Program (G-LTMP)

The Guam long-term coral-reef monitoring program (LTMP) represents a complementary program to the national monitoring program conducted by NOAA-NCRMP since 2012. The key differences are survey designs that were focused on examining MPA efficacy through time and only sampled in MPA and reference locations (Burdick 2023). 20 to 35 sites were established in each MPA and reference location annually, resulting in 2 to 5 years of comparative data depending on the MPA. Aggregation and comparative binomial testing for species presence within MPA were as noted above.

2.2.6 | Guam Long-Term Monitoring Program-Resilience (G-LTMP-R)

The Guam long-term monitoring program also conducted two snapshot resilience-based surveys associated with the 2015 to 2017 El Nino Southern Oscillation events. During each timeframe, 20 sites were selected for investigation around the island at a shallow (3 m) and intermediate (8 m) depth. Six replicate SPC surveys were conducted along 3 × 50 m transect lines. Aggregation and comparative binomial analyses for MPA presence were as noted above.

2.2.7 | Guam Stereo Video (G-SV)

Guam stereo video data were collected during two time periods a decade apart (2011 and 2021) to investigate trends in fish composition, biomass, and size-structure (Taylor et al. 2015, 2022). Surveys were conducted across 17 representative Guam sites using timed swims with surface-towed GPS at two depths (6–10 m and 18–20 m) that covered approximately 1 ha per site based upon GPS measured distances. Fish within 8 m in front and 2.5 m on either side of the camera were identified to species level, annotated by colour phase, and measured to the nearest mm fork length. Sites span across MPAs and a range of environmental and anthropogenic factors. Over 15,000 fish were measured, with most representing target parrotfish and surgeonfish that were the focus of past studies. Biomass and size were aggregated to the site-depth level and examined across MPAs and geography as noted above.

2.2.8 | Micronesia-FD

FD datasets have been collected through many collaborative efforts over the past decade from Guam, Commonwealth of the Northern Mariana Islands (Saipan), Yap, Pohnpei, Chuuk, Kosrae, Palau and the Marshall Islands (Majuro and Arno atolls). Standardised, intensive efforts were conducted across 1 year to represent major seasons and capture a snapshot of each island-year. Daily visits to prominent fish markets and/or fishers were made where interviews were conducted and fish measured to the nearest cm fork length. These surveys provided between 30,000 and over 200,000 fish measurements depending upon the island size (Houk et al. 2012, 2017, 2018a; Cuetos-Bueno et al. 2018, 2019; Rhodes et al. 2018). For Guam, comparative data originated from recent G-DAWR creel surveys over the past decade as well as a recently completed thesis project in 2021 that collected more extensive data across the year (Sablan et al. 2025). Proportional contributions to landings and the skewness of size-structures were regressed against humans-per-reef-area, a common fishing pressure index that has previously been used. Regression modelling followed the statistical checks noted above for time-series data.

2.2.9 | Micronesia-FI

FI datasets have been collected over the past 10 years from many jurisdictions across Micronesia, including: Guam, Commonwealth of the Northern Mariana Islands (Saipan and Tinian islands), Yap, Pohnpei, Chuuk, Kosrae, the Republic of Palau, and the Republic of the Marshall Islands (Majuro and Arno atolls). Data were collected by many organisations and individuals in a collaborative partnership that defines the Micronesia coral-reef monitoring program (https://micronesiareefmonitoring.com/). Data from Guam were associated with the ridge-to-reef project noted above and other ongoing efforts by the same principal investigators that have island-wide coverage. For each island, long-term monitoring site selections were stratified across (i) management regimes, (ii) wave exposure, (iii) islands and (iv) major reef habitats, to be representative of each island (Houk et al. 2015), with the total number of sites proportional to the area of reef habitat. The sizes and abundances of target food-fishes were collected using SPC protocols described above for the Guam ridge-to-reef dataset. Proportional contributions to landings were regressed against humans perreefarea as noted above for the Micronesia-FD dataset.

2.3 | Data Analyses

Prior to analyses, target species within each data source were evaluated in terms of their "presence" (95% confidence intervals surrounding mean values per unit replication >0) and "resolution" (standard deviations that were not larger than 50% of means). This process was previously documented and provided a list of species recommended for formal analyses within each data source (Houk and Taylor 2023).

Each species was then examined with respect to fishing pressure gradients that have been previously defined, including: temporal trends in (proportional) biomass and size-structures, spatial trends in biomass and size across islands (i.e., human gradients), or spatial trends in biomass and size across MPA status (Houk et al. 2012, 2017; Taylor et al. 2014; Cuetos-Bueno et al. 2018). While statistical examinations differed, the effect sizes defined by model estimates provided a comparable metric of species status. For instance, effect sizes for regression models examining temporal trends defined the direction and magnitude of biomass decline through time, with larger negative values indicating larger declines and lower species status. Similar effect sizes were generated for spatial regression and comparisons across MPA status. These effect sizes were normalised across species within each data source, providing values between 0 and −1 to represent a weak or non-significant response to the fishing pressure gradient examined compared to a strong negative response, respectively. This normalisation process allowed for integrating results across data sources as furthered below. In addition, standardised data collected from the same sites through time and paired MPA-reference locations were used to control for potential confounding factors known to influence fish assemblages, such as habitat or wave energy.

Regression models were used to examine temporal trends in G-DAWR creel landings between 1990 and 2020 and spatial trends across human-population-per-reef densities that represented each Micronesia island (Micronesia FI and FD). Both linear and polynomial trends were examined for best fits. Linear trends indicated a steady decline/improvement through time or across space, while polynomial trends indicated a rapid increase/decrease followed by stasis (Houk et al. 2018a). Time-series regressions were performed using R base packages, and 3-year rolling averages were used for time-series data to filter out random fluctuations and increase the signal-to-noise ratio (R Development Core Team 2010). The best-fit regression models were determined based upon their goodness of fit (R^2) and significance (p-values) while ensuring normality of residuals and lowest Akaike Information Criterion (AIC) scores. Estimates from the best-fit models represented effect sizes that were used when comparing species responses. In the four instances when polynomial regression models had a better fit compared to linear models, the estimate from the first term was used as the effect size to draw comparisons across species with as second order curvature did not change the nature of the relationship.

Remaining data with limited temporal trends across 1–3 timeframes were treated discretely, while pairwise testing across MPA status was conducted for paired sites in similar habitats. Size and (proportional) biomass data were aggregated to the site level, and comparative models were assessed for their significance (p-values and t-values) and effect sizes (estimates) while ensuring normality of residuals (R Development Core Team 2010). Biomass data were log-transformed for normality when appropriate, while size data were not transformed. In two instances noted in the results, binomial models were used instead of linear models (i.e., t-tests) due to limited species presences in NOAA-NCRMP and G-LTMP datasets. Binomial models represent one class of generalised linear models and were assessed for significance using likelihood ratios that draw comparisons with null models and z-values from the Wald test to ensure estimates were greater than their standard errors (R Development Core Team 2010).

2.3.1 | Cluster Analyses

The effect sizes associated with each statistical test provided a means to evaluate the relative exploitation status of target species. Statistical effect sizes were entered into a *species × data source* matrix. Columns (i.e., effect sizes across species within each statistical test) were all normalised between 0 and −1 as described above. Heat maps were then used to visualise the magnitude of species responses across all data sources, and cluster analyses were performed to objectively group target species with similar responses to fishing pressure gradients. Cluster analyses were based upon Euclidean distances calculated for all pairs of species responses, and hierarchical clustering was implemented using the *hclust* function in package *pheatmap* in R (Kolde 2015). Clustering was bootstrapped 1000 times until the top clusters were consistently retained, and elbow plots revealed that adding more clusters did little to capture additional variance structure (i.e., elbow plots showing the exponential reduction, or decay, in within-cluster sum of squares as more clusters are added). Cluster analyses were performed using all data sources and for FI or FD data sources independently. This was done to appreciate any potential differences or biases that may be due to the nature of data collection.

2.4 | Life-History Database and LBSPR

The present study synthesised a database of local life-history parameters for 18 of the target coral-reef fishes derived from Guam (86%) and nearby Micronesia (14%) (Appendix S1). These life-history data were generated from fish captured across dominant and representative fishing sectors including night/day spearfishing, bottom fishing, and various forms of net fishing. Of relevance to our LBSPR modelling, the studies derived best-fit parameters for asymptotic length (L_{inf}), growth coefficients (K, year^{-1}), natural mortality (M, year^{-1}), length-weight coefficients, size and age at 50% and 95% maturity ($L_{50/95}$ or $A_{50/95}$).

Because the variability and dynamics of life-history parameters have strong influences on the outcomes of LBSPR modelling (Medeiros-Leal et al. 2023; Prince et al. 2023; Coscino et al. 2024), we also derived life-history parameters using two other approaches for comparative purposes. An influential study recently quantified universal relationships between the ratios of (M/K) and (L_{50}/L_{inf}) for dominant fish families derived from an extensive global database (Prince et al. 2023). Therefore, we used our local estimates of L_{50}, along with the derived family-level ratios of (L_{50}/L_{inf}), to back-calculate a second set of L_{inf} values that correspond with the derived family-level (M/K) values. Third, another influential study examined L_{50} values derived from histological studies against stereo video estimates of L_{50} from spawning aggregations and concluded that histology estimates may potentially underestimate functional maturity, defined by presence in the spawning aggregation, by up to 15% (Prince et al. 2022). Therefore, we repeated the same process but increased our L_{50} estimates by 15%. This approach provided the third set of inputs for LBSPR.

Both modern and historical catch data were used to generate length vectors for each species for LBSPR. G-DAWR-creel data between 1990 and 2009 were binned to represent historical catch data with sufficient sample sizes. Meanwhile, G-DAWR-creel data between 2010 and the present were combined with a second FD data collection program that began in 2021 to represent modern catch data (Sablan et al. 2025). Importantly, the modern period matches the time range FI data were collected.

LBSPR was performed for target species that had local life-history data and a minimum recommended sample size equal to the number of bins in the optimised catch vector histograms multiplied by 10 (Hordyk, Ono, et al. 2015), which was between 50 and 100 measurements for most species. Hordyk, Ono, et al. (2015) reviewed how increasing sample sizes beyond minimum values, up to 10,000, served to reduce the standard error surrounding SPR estimates but not the accuracy, assuming catch data were representative of the entire fishery (i.e., $\mathrm{SE}=\mathrm{SD}/\sqrt{n}$, where n is sample size). Our data were representative and contained hundreds of individuals for most species (Table 1), matching sample sizes from previous studies in our region and multispecies coral-reef fisheries elsewhere (Nadon 2019; Ahrens and Nadon 2023; Prince et al. 2015).

LBSPR analyses followed several studies that previously defined the approach and developed an informative R package (Hordyk, Loneragan, et al. 2015; Hordyk 2019; Nadon 2019; Ahrens and Nadon 2023). Given significant documentation, a brief description is provided. LBSPR used life-history parameters to estimate the size distribution and age structure of unexploited populations from key life-history parameters, which were then compared against the catch data. Key life-history parameters included L_{inf}, L_{50}, L_{95}, M, and K. In complement, length-based vectors from both historic and modern catch data representing sizes-at-capture were used to estimate the selectivity size, or SL_{50} and SL_{95}, 50% and 95% respectively. By comparing characteristics of unexploited populations versus representative landings, the ratios of fishing mortality to natural mortality (F/M) and spawning potential (SPR) were calculated. Notably, F/M and SPR are both key outcomes of the LBSPR modelling process that are inversely related, but not linearly. While F/M estimated fish removal across the entire range of selectivity sizes, SPR placed added value on the size class associated with each fishing mortality based on the exponential relationship between length, weight, and gonad development. Thus, as fishing mortality increases, the SPR decreases rapidly at first but starts to level off near zero as fishing removes the vast majority of spawning biomass. We last review three key assumptions associated with the LBSPR process: (1) constant recruitment, growth and mortality, (2) fish stocks are at equilibrium and (3) catch data are representative of fishing extraction across the entire fishery and all gears.

SPR values indicate the proportion of spawning biomass that remains within a fished population, and a benchmark value of 0.3, or 30%, has been recommended to protect against recruitment overfishing (Goodyear 1993; Mace and Sissenwine 1993). Meanwhile, F/M values near 0.3 represent conservative benchmarks thought to promote high yields with low stock depletion, while values closer to 1 are associated with MSYs. Similar fishing mortality metrics include F/F_{30}, representing the ratio of fishing mortality observed versus fishing mortality calculated when SPR is forced to 0.3, or 30%. We note the mathematical similarity between F/M and F/F_{30} because mortality and growth are held constant for LBSPR analyses, and F_{30} approaches M when SPR is set to 30%. While all benchmarks are contextually relevant, our results are framed in the relative values of F/M and SPR across species. We selected 0.3 for both to contrast a more conservative benchmark for F/M and a less conservative benchmark for SPR, but again note the relative use of each.

We last forecasted the modelled SPR outcomes across a wide range of selectivity sizes and F to visualise what type of management may be most relevant for each species. Small ratios of SL_{50}/L_{50} resonated more with the regulation of size-at-capture, while large ratios of F/M resonated more with the overall regulation of fishing effort across all size classes.

3 | Results

A mean of 7 ± 2.5 statistical tests was performed for each target species to assess trends across space, time, and other fishing pressure gradients derived from the nine unique FI and FD data sources (Figure 2). Six representative species associated with both spearfishing and bottom fishing were selected to visualise diverse responses to fishing pressure gradients associated with the two representative data sources (Figures 3 and 4). Examples included: (i) time-series trends across decades that revealed shifts in proportional biomasses for dominant species targeted by both spearfishing and bottom fishing (Figure 3), and (ii) spatial regressions in size-structure across islands in Micronesia for these same species (Figure 4). More broadly, the complete set of responses for all species and all statistical tests were depicted in a heatmap and provided in a table (Figure 2 and Appendix S2).

Overall, declining size and biomass trends existed for 35% of the statistical tests performed using both FD and FI data (Figure 2). Fewer instances of increasing biomass and size trends existed in the FD (15%) or FI (6%) examinations. Rare instances of increasing biomass or size trends were associated with the largest gradients of fishing pressure examined, including temporal trends across decades on Guam or spatial trends across islands in Micronesia. Meanwhile, non-significant trends existed between 48% (FD) and 60% (FI) of the time, most often for small-bodied species that had asymptotic lengths less than 30 cm, for species-datasets that were associated with high standard deviations compared to mean values, and for datasets examined with presence/absence binomial models (Figure 2).

TABLE 1 | Results from length-based spawning-potential-ratio (LBSPR) modelling conducted for target species using local life-history data for model inputs.

	n-LH	n-C	min	max	L_{50}	L_{95}	M/K	L_{inf}	SL_{50}	SL_{95}	F/M_1	F/M_2	SPR_1	SPR_2	*S*	*M*	FI/FD
Hipposcarus longiceps	265	214	10	50	32.9	40.6	0.53	43.4	15.9	19.9	2.57	2.19	0.11	0.09	**	**	**4**
Siganus argenteus	425	165	9	30	21.8	27.0	0.63	27.4	13.5	17.6	1.00	1.47	0.29	0.18	**	**	3
Acanthurus lineatus	187	273	9	26	17.4	18.6	0.18	19.0	11.1	13.8	0.00	1.36	1.00	0.30	**	**	5
Acanthurus xanthopterus	60	100	9	38	27.6	29.7	1.00	35.4	12.3	16.4	0.12	0.56	0.77	0.33	**	**	5
Scarus altipinnis	53	104	11	42	25.1	28.6	0.45	33.9	14.8	18.6	0.38	0.98	0.63	0.33	**	**	**4**
Naso unicornis	247	466	11	54	29.2	33.9	0.82	49.3	14.9	20.5	1.04	0.69	0.24	0.37	**	**	5
Caranx melampygus	151	482	9	73	30.4	33.3	0.85	53.3	17.0	28.9	0.71	0.68	0.38	0.40	**	**	3
Lethrinus rubrioperculatus	174	901	6	50	23.2	27.2	0.66	31.5	18.7	23.4	0.33	0.66	0.71	0.49	*	**	**1**
Chlorurus microrhinos	80	122	15	48	30.8	36.8	1.03	45.7	27.9	43.7	0.11	0.48	0.83	0.60		**	**1**
Variola louti	287	190	12	47	26.0	31.8	1.32	43.7	21.4	30.7	0.29	0.32	0.74	0.65	*	*	**1**
Chlorurus frontalis	83	250	12	52	24.0	26.3	0.54	37.2	19.5	27.6	0.35	0.32	0.64	0.69	*	*	**2**
Scarus rubroviolaceus	224	57	18	48	27.1	27.9	0.92	43.2	19.0	21.4	0.00	0.16	1.00	0.79	*	*	**4**
Acanthurus olivaceus	100	104	10	26	16.8	18.6	0.29	21.2	9.7	9.8	0.00	0.06	1.00	0.92	**		5
Mulloidichthys flavolineatus	273	252	10	30	15.8	19.6	0.68	24.5	9.7	10.3	0.00	0.01	1.00	0.99	**		**2**
Naso lituratus	126	676	9	30	14.5	20.8	0.21	21.6	10.4	12.1	0.14	0.01	0.85	0.99	*		5
Chlorurus spilurus	347	193	13	30	14.4	18.1	0.49	21.8	18.2	24.9	0.00	0.00	1.00	1.00			**2**
Scarus psittacus	114	203	11	33	10.3	20.7	0.77	20.7	16.0	22.2	0.00	0.00	1.00	1.00			5
Scarus schlegeli	116	135	11	40	19.7	24.9	0.51	25.2	18.8	30.2	0.00	0.00	1.00	1.00			5

Note: Key metrics: Sample sizes from life-history (n-LH) and modern catch data (n-C), minimum and maximum sizes recorded in catch data, sizes at 50% (L_{50}) and 95% (L_{95}) maturity, mortality divided by growth rate (M/K), asymptotic size (L_{inf}), sizes at 50% (SL_{50}) and 95% (SL_{95}) fishing selectivity based on modern data only, and the ratios of fishing-to-natural mortality ($F/M_{1,2}$) and spawning potential ratio ($SPR_{1,2}$) based upon both historic and modern catch data binned across 1990 to 2009 and 2010 to present, respectively. Two summary columns are provided at the end: (*S*)ize highlights the magnitude of SL_{50}/L_{50} (** < 70% or lowest, *between 70% and 85% or low, blank for > 85%), while (*M*)ortality highlights the magnitude of $(F/M)/0.3$ (** > 100% or highest, *between 30% and 100% or high, blank for $F/M < 30\%$) based on modern catch data. Last, FI/FD refers to the outcomes of the cluster analysis classifying species responses to fishing pressure gradients with bold representing clusters that had largest declines in biomass and/or size (see Figure 2). For comparisons with alternative LBSPR modelling scenarios and full results of LBSPR with historical catch data see Appendix S1.

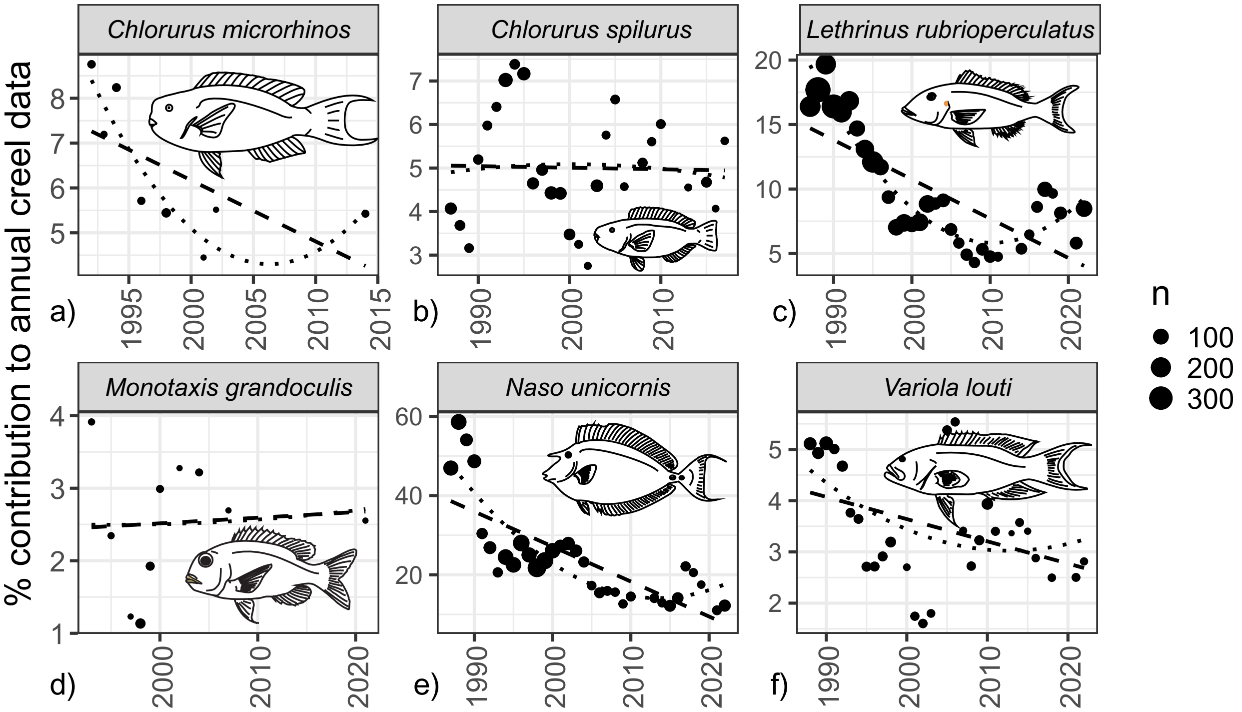

FIGURE 3 | G-DAWR creel data trends in proportional biomass through time. Results for six representative species associated with the freedive spearfishing and bottom fishing sectors are shown, however, analyses were conducted for all species with sufficient data. Dashed lines indicate linear fits through the data points while dotted lines represent second order polynomial fits. Lines served to visualise potential models that were investigated for their best fit, while statistical tests provided effect sizes that populated the heatmap (Figure 2). Circle sizes indicate number of fish measured by the creel program in each year.

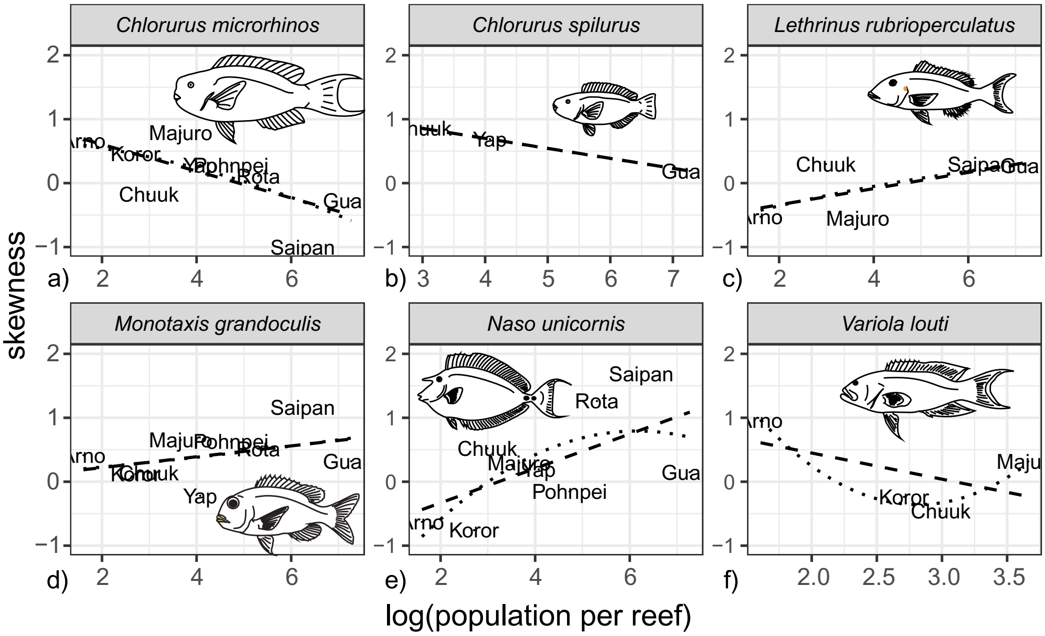

FIGURE 4 | Skewness of size-structures for six representative species associated with fisheries-dependent data across Micronesia. Positive skewness indicated that size-structures had a greater proportion of smaller fish. Data were derived from freedive spearfishing and bottom fishing sectors similarly for all islands (methods). Dashed lines indicate linear fits through the data points while dotted lines represent second order polynomial fits. Lines served to visualise potential models that were investigated for their best fit, while statistical tests provided effect sizes that populated the heatmap (Figure 2).

The heatmap and cluster analyses suggested five groups of species provided the optimal number of clusters to reduce within cluster deviances, or sums of squares, and account for the majority of variation in the species responses. The distinctions between the species clusters were related to several factors, including: the strength or effect size of the examinations, their presence in FD versus FI data sources, and interestingly, whether size-versus-biomass responses to fishing pressure were most pronounced. Clusters were ordered based upon their height in the dendrogram indicating greater distinctness and summarised below.

1. Cluster 1—Three species with *high sensitivities to fishing pressure showing large negative effect sizes in biomass* through time, most common based upon FD (primarily) and FI (secondary) data. Both spearfishing and bottom fishing species were included, representing large and dominant parrotfish, emperorfish, and grouper (L_{inf} > 40 cm).
2. Cluster 2—Six species with *high sensitivities to fishing pressure showing large negative effect sizes in size structure* most common based upon FI (primary) and FD (secondary) data. Both spearfishing and bottom fishing species were included representing mixed sizes of parrotfishes, large snappers, one large emperorfish, and one small goatfish.
3. Cluster 3—Five species with *moderate sensitivities to fishing pressure showing mixed effect sizes for both size-structure and biomass* based upon FD (primary) and FI (secondary) data. Comparatively less data were available to assess the species in this group that included mainly small groupers, a small snapper, a small rabbitfish, and a large trevally.
4. Cluster 4—Five species with *high sensitivities to fishing pressure showing large negative effect sizes for both biomass and size-structure* based upon FI (primary) and FD (secondary) data sources. Species at the top of this cluster had greater impacts on their size-structures while species at the bottom had greater impacts on their biomass. Both spearfishing and bottom fishing species were included, representing large parrotfishes and emperorfishes.
5. Cluster 5—Eleven species with the *lowest sensitivities to fishing pressure showing mixed effect sizes for both biomass and size-structure* based upon FD (primary) with FI (secondary), with notable differences from cluster 3 due to FI data having a lot of non-significant trends. Mainly spearfishing species were included representing a diverse group of mostly small herbivores and detritivores, but notably one large-bodied surgeonfish and one large rudderfish.

Unsurprisingly, 14 large-bodied species with relatively slow growth and/or low natural mortality were most sensitive to fishing pressure (Figure 2, clusters 1, 2, and 4; Table 1). Yet, five of these species (36%) had largest effect sizes associated with biomass declines (cluster 1 and bottom of cluster 4), 5 (36%) had largest effect sizes associated with size-structures (top of cluster 2), and four (28%) had equal effect sizes across biomass and size-structure. These remarkable distinctions in compensatory density dependence revealed by size-versus-biomass declines were not related to taxonomy, trophic level, or body size. Instead, species represented a mixture of large-bodied parrotfishes, snappers, groupers, and emperorfishes. Conversely, moderate, weak, or non-significant trends were revealed for most small-bodied, higher-turnover counterparts. Notable exceptions included three large and dominant herbivores/detritivores that had weak or mixed effect sizes associated with fishing pressure sensitivity, including one trevally, surgeonfish, and rudderfish (*Caranx melampygus*, *Naso unicornis*, and *Kyphosus cinerascens*, respectively, Figure 2).

These species patterns were similar whether using combined or independent FD or FI data sources for cluster analyses (Figure 2 and Appendix S3). The few instances where assessments differed occurred when species were well represented by one data source but absent or rare in the other (e.g., some bottom fish were more common, or only present, in FD data). Despite similar patterns across species, one interesting outcome was that species declines were stronger and more frequent in FI compared to FD data (Appendix S3, normalised values used in all instances, colour gradients indicated effect sizes).

3.1 | LBSPR

LBSPR analyses performed for 18 target species with locally derived life-history data suggested that only six species had SPR values near or below the 30% benchmark, representing two small rabbitfishes, one small and one large surgeonfish, and two large parrotfishes (Table 1). In contrast, FI and FD data examination revealed high sensitivity to fishing pressure for both large parrotfishes only, but also for many other target species with SPR values above 30%, often much larger (Figure 2, Table 1). Meanwhile, the ratio of fishing-versus-natural mortality (F/M) represented a second metric of fishing pressure derived by LBSPR. Twelve species were near the 30% benchmark that was numerically similar but functionally more conservative compared to SPR (Section 2). Among these, only six had large statistical effect sizes associated with FI and FD data, while others had mixed responses. As expected, more species crossed the more conservative F/M benchmark compared to SPR, but there was a similarly low correspondence with FD and FI effect sizes (Table 1). Last, five small target species were associated with fishing mortality below 0.01%, which was unrealistic based on presences in FD data sources.

Comparisons of SPR and F/M metrics between the modern (2010 to present) and historical (1990 to 2009) time periods revealed declining trends for nearly 70% of species, especially large-bodied species with asymptotic sizes greater than 30 cm (Table 1 and Appendix S1). The SPR declines mirrored the FI/FD trends for several large parrotfishes, emperorfishes, and one grouper (*Chlorurus microrhinos*, *Scarus altipinnis*, *Scarus rubroviolaceus*, *Lethrinus rubrioperculatus*, and *Variola louti*). Yet, large declines in SPR were noted for two surgeonfishes that showed limited FI/FD trends (Table 1, the smaller surgeonfishes *Acanthurus lineatus* and *A. xanthoperus*). Meanwhile, consistently low SPR with limited change through time was found for three large-bodied fishes common to both historical and modern landings (*Hipposcarus longiceps*, *Naso unicornis* and *Caranx melampygus*). Last, many small-bodied target species had unrealistically low fishing mortality based on historical catch data, similarly reported with modern catch data above, limiting any comparisons across the two time periods.

Alternate scenarios for LBSPR modelling using locally derived L_{50} along with invariant M/K ratios to generate a second set of L_{inf} estimates revealed similar findings in terms of SPR outcomes, but lower F/M values. SPR values were $<30\%$ for a subset of 5/6 of the species noted above, while F/M values were $>30\%$ for a subset of 8/12 species noted above (Appendix S1). Last, the final LBSPR simulations that added 15% to our locally derived L_{50} to generate a third set of L_{inf} doubled the number of species with SPR $<30\%$ and $F/M > 30\%$. However, this process resulted in L_{inf} estimates that were larger, often much larger, than reported in catch data (Appendix S1). Despite more species with low SPR, the outcomes had similar inconsistencies when compared to FD and FI trends that were noted above.

Interestingly, despite inconsistent outcomes between the FI/FD trends and LBSPR metrics, the nature of potential fishing impacts to size-structures versus biomass appeared to align better. We examined the relative values of SPR and F/M across species as potential indicators (i.e., species ranks within each indicator). Two of the three species with the largest biomass declines from FI/FD data had high F/M ranks along with moderate SPR ranks, suggesting greater fishing mortality across all sizes (Table 1, *C. microrhinos* and *L. rubrioperculatus*, FI/FD cluster 1). Further, all three species with equal impacts to both size and biomass from FI/FD data had high F/M coupled with low SPR ranks, suggesting high fishing mortality across all sizes but highest among large individuals indicating size selectivity and/or compensatory recruitment (FI/FD cluster 4). Last, one of the three species with the largest size declines from FI/FD data had moderate SPR and F/M ranks (cluster 2); however, the lack of clarity for this group may be an artefact of small-bodied species that had LBSPR modelling concerns noted above, and early maturation relative to L_{inf} in the large-bodied parrotfish *Chlorurus frontalis*.

We last visualised the potential benefits of managing size (SL_{50}) versus effort (F) through a series of SPR contour plots (Figure 5). These findings suggested that LBSPR outcomes may recommend whether managing size-or-effort may be most beneficial for each target species.

4 | Discussion

Diverse coral-reef fisheries were assessed using nine unique sources of data that provided a consensus of the status and trends for 30 dominant target species across Guam and Micronesia. FI and FD data unsurprisingly revealed that large-bodied species of herbivores, secondary consumers, and predators were most sensitive to the gradients of fishing pressure examined. These findings resonated with past studies reporting: (i) declines in size and biomass for many target species on Guam across space and time (Taylor et al. 2014, Houk et al. 2018a, Taylor et al. 2022), (ii) regionally low, often lowest, fish biomass for many species and overall fish biomass on Guam compared to other Pacific islands (Williams et al. 2012; MacNeil et al. 2015; Houk et al. 2021), and (iii) significantly lower catch success and observed biomass on leeward, more accessible reefs compared to windward, wave-exposed reefs (Houk et al. 2022; Taylor et al. 2022; Sablan et al. 2025). Yet, the interesting caveat was that FI data sources had a greater tendency to report declining trends compared to FD sources. This was thought to be an artefact of spatial expansions in fisheries, which can stabilize catch dynamics through periods of time. In support, past studies have noted spatial expansions in fisheries landings while FI data were collected from long-term monitoring of the same reefs through time (Houk et al. 2018a).

In contrast, data-poor LBSPR models derived from modern catch data using local life-history data, or local L_{50} coupled with invariant ratios of M/K and L_{50}/L_{inf}, revealed that SPR and F/M metrics were inconsistent predictors of stock status. These inconsistencies both heightened and reduced management concerns for many target species. These findings were corroborated by past LBSPR studies using varying assumptions for life histories, suggesting that only 4 out of 12 species (Nadon 2019), and 2 out of 7 (Ahrens and Nadon 2023), had median SPR values below the 30% threshold. In all instances, large-bodied species with strong biomass declines but limited size-truncation, as well as several small-bodied species, appeared to be misrepresented. Conversely, the smaller subset of species that appeared to have the best agreement between LBSPR metrics and FI and FD data streams were large-bodied species with notable size-truncation as a primary response to fishing pressure (L_{inf} estimates between 30 to 60 cm, large parrotfishes and surgeonfishes such as *Naso unicornis* and *Hipposcarus longiceps*, Table 1).

Last, temporal trends in F/M and SPR revealed declines that better matched FI/FD trends for large-bodied species, notably FI/FD clusters 1 and 4, but not small-bodied species. Influential life-history attributes associated with small-bodied species are reviewed below. In addition, beneficial attributes of snapshot LBSPR metrics are linked to fisheries policies that may be most effective to support stakeholders using simplified indicators such as multispecies biomass criteria (McClanahan et al. 2015; McClanahan 2018), local knowledge (Johannes et al. 2000), or indicator species that appeared to work best within the LBSPR framework (Barnett et al. 2019; Cope et al. 2023).

4.1 | Species Attributes, Life Histories, and LBSPR

The presence or absence of strong size-truncation, or strong compensatory density dependence, appeared to be the greatest concern for snapshot LBSPR assessments compared against the common 30% benchmarks. Because SPR is rooted in the theory that larger individuals have exponentially more reproductive output (Barneche et al. 2018), species with limited size-truncation had relatively large SPR values despite large biomass declines reported by FI/FD data (e.g., *Chlorurus microrhinos*). Interestingly, this does not violate the LBSPR assumptions of consistent recruitment because differences appeared to represent a species attribute, with some species consistently having less size truncation compared to biomass depletion (Houk et al. 2018a, 2021). One explanation is that species may express density dependence in either a regulatory or compensatory manner, whereby the removal of adults reduces or enhances recruitment, respectively (Rose et al. 2001; Houk et al. 2021; Medeiros-Leal et al. 2023). Many attributes of population ecology and biology could contribute to these contrasting responses, including ontogeny within or across habitats, varying home-range sizes and foraging strategies, and competitive interactions among recruits of differing species in similar niches.

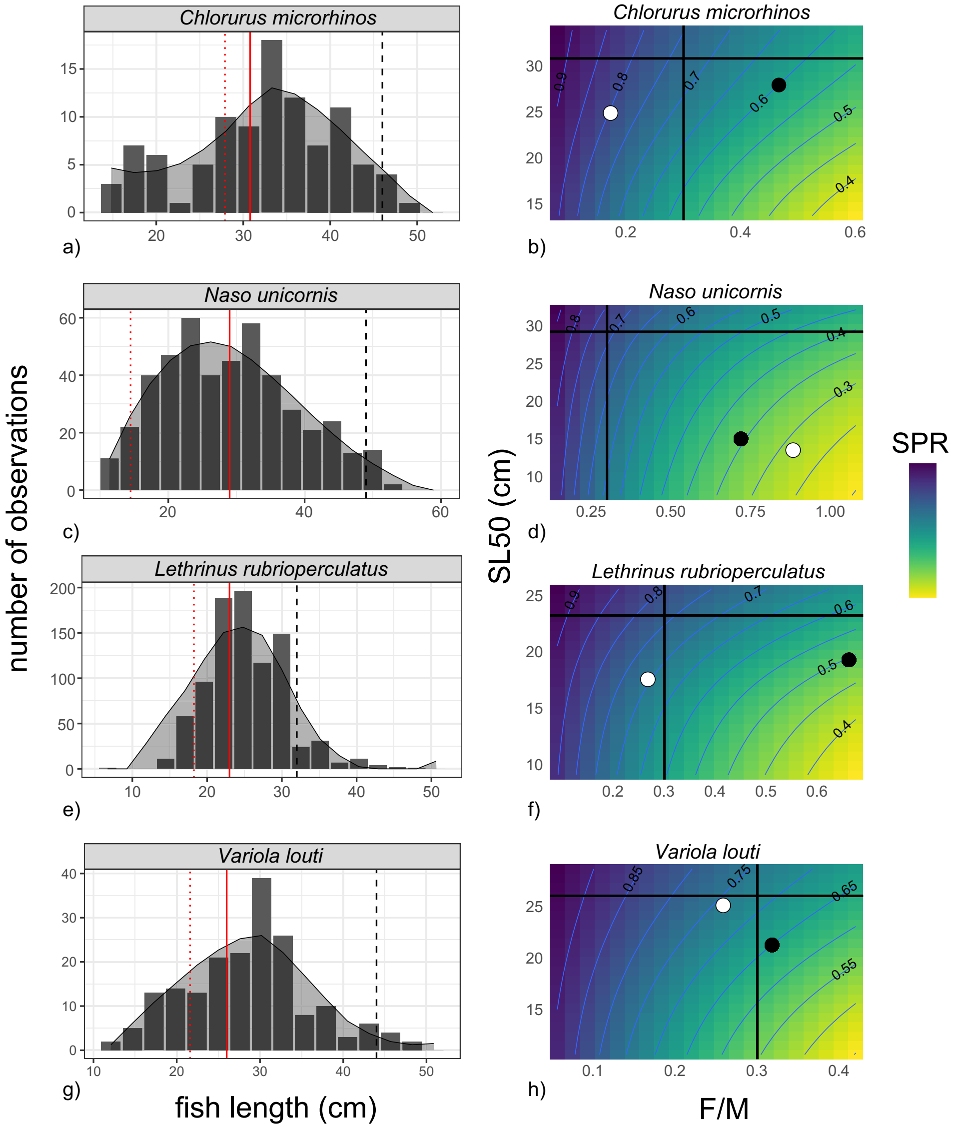

FIGURE 5 | (a–h) Results from length-based spawning-potential-ratio (LBSPR) assessments for five representative species with locally derived life-history data. For each species, histograms (left) depict the sizes-at-capture from modern landings placed in optimal size bins by the LBSPR process. Red lines indicate the L_{50} (solid) and SL_{50} (dashed), or the sizes at 50% maturity and selectivity. Black dashed lines indicated the asymptotic lengths (L_{inf}). Key LBSPR outputs are highlighted on the contour plots (right): F/M, or fishing mortality divided by natural mortality, SPR, or the ratio of the modelled spawning biomass compared to unfished spawning biomass, and SL_{50}. The large black dot represents SPR derived from modern landings (2010 to present) while the white dot represents SPR from historical landings (1990 to 2009). Contours estimate SPR across hypothetical fishing pressure and selectivity gradients. Horizontal reference line indicates the L_{50} to show the relationship between harvest size and size-at-maturity. The vertical reference line represents 0.3, or the 30% benchmark (Section 2).

Second, we agree with past studies describing the sensitivity of SPR outcomes to a few life-history parameters: L_{50} and L_{inf}, or the maturity and asymptotic lengths, and the balance between K and M, or growth and natural mortality (Medeiros-Leal et al. 2023; Prince et al. 2023; Coscino et al. 2024). Many small-bodied species with rapid growth and maturity across small increments in age had a highly sensitive inflection point in modelled SPR leading to fully exploited ($SPR << 0.3$) or unexploited ($SPR \sim 1$) status (e.g., comparisons of SPR outcomes for *Acanthurus lineatus* between historic and modern time periods, Table 1). For these species, the relationship between L_{50} and L_{inf} becomes highly influential in predicting stock status, placing a greater reliance on life-history attributes compared to catch data. In support, we note at least one species had relatively small L_{50} to L_{inf} ratios consistently reported from many Pacific Islands (*Chlorurus spilurus*, unpublished Pacific life-history database, author B.T.). Similar sensitivity emerged across species with variable mortality. The interesting biphasic mortality patterns recently revealed for surgeonfishes showed a coupling of fast growth with unusually long life spans (Taylor, McInnis, et al. 2024). While fishing pressure can influence lifespan, the biphasic mortality pattern persisted across the gradients of fishing pressure examined here. In turn, the diminished M/K values lowered SPR outcomes. These findings expanded on a concept suggested for short-lived species and revealed that when M and K become decoupled inconsistent outcomes can emerge (Hordyk, Loneragan, et al. 2015).

We summarise that variability in density dependence, size-at-maturity, and mortality represented key attributes that were ultimately engrained in species identity and not necessarily correlated with asymptotic body size as many fisheries models assume. These differences appeared to be the primary drivers of disparate outcomes from snapshot LBSPR compared to FI/FD data sources. Data quantity and quality were also potential concerns. Care was taken to account for potential sources of errors such as species identifications, FI observer calibrations, and reviewing life-history data from as many regions as possible to ensure consistency. Yet, there were some factors we were not able to account for such as gender-specific growth curves because FI/FD data streams were not separated by sex.

4.2 | Management

Four situations appeared most desirable when using LBSPR to assess the status of multispecies coral-reef fish stocks with or without FI data. Hierarchically, these included: (i) temporal assessments of individual species given sufficient data and relying upon the magnitude of trends, (ii) snapshot spatial comparisons of individual species across no-take marine protected areas and fished reefs, also relying upon the magnitude of trends, (iii) snapshot LBSPR assessments relying on comparisons against 30% benchmarks for species that best match key assumptions (e.g., strong compensatory density dependence and representative stock structure depicted by the catch data), and last, (iv) snapshot assessments across species to reveal whether size-or-biomass responses to fishing pressure may be strongest, relying upon comparisons of SL_{50} to L_{50} in combination with simplified data sources or expert knowledge to trigger management. Ultimately, these four approaches aim to recommend whether size-or-effort-based management may be most appropriate and the urgency for implementation. We do not further specify policies here but note that many options are available within both management classes. For instance, size policies could regulate minimum, maximum, or slot sizes for harvesting. Meanwhile, fishing effort can be regulated by many approaches including gear, location, season, or access.

Importantly, several iconic species were absent from our study despite attempts to gather as much data as possible. Two of the largest target species in coral-reef fisheries had insufficient data for any assessments: the bumphead parrotfish (*Bolbometopon muricatum*) and the Napoleon wrasse (*Cheilinus undulatus*). We had a similarly low presence of many large groupers and other charismatic species. Alternative approaches will be needed to assess these rare species associated with coral-reef fisheries. However, stakeholder knowledge and traditional forms of management often exist (Aswani and Hamilton 2004; Friedlander et al. 2023).

4.3 | Future Directions

While coral-reef fisheries are spread across many independent island nations, a common set of dominant target species exists across oceanic basins within the tropical Pacific. The species-level guidance reported here was not unique to any island as similar patterns continue to emerge across our Micronesia study region (Houk et al. 2017; Cuetos-Bueno et al. 2018, 2019; Rhodes et al. 2018). Collaborative networks and intuitive approaches such as Fish Path could be enhanced to link size-versus-effort management guidance with both species identities and potential policies to choose from (Dowling et al. 2023). Meanwhile, islands with limited data can conservatively use our species guidance to recommend policies while focusing on simple, cost-effective fisheries (in)dependent data streams to determine when management should be triggered or evaluated.

Yet, many Pacific islands now collect FD, FI, life-history and stock assessment data, though with varying consistency and resolution. Our results highlight the interconnected nature of these independent data sources, suggesting that the strongest metrics from all available data could be synthesised into simplified indicators of stock status. This cross-disciplinary approach has a foundation for data-limited settings and may offer simplified stock guidance (Harford et al. 2021). Future work for data-limited fisheries should continue to synthesise information across independent data sources rather than treating them as competing alternatives.

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Conflicts of Interest

The authors declare no conflicts of interest.

Data Availability Statement

Data for our species meta-analysis were synthesised from many independent sources including published studies, one online data portal (https://micronesiareefmonitoring.com/), requests to authors and collaborators, and provided in our Appendix of life-history data. These synthesised data are available upon request to relevant authors that can be identified through our citations and methods.

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Supporting Information

Additional supporting information can be found online in the Supporting Information section.