BioOne COMPLETE

Quantifying Species Abundance Trends in the Northern Gulf of California using Local Ecological Knowledge

Author: Ainsworth, C. H.

Source: Marine and Coastal Fisheries: Dynamics, Management, and Ecosystem Science, 3(1) : 190-218

Published By: American Fisheries Society

URL: https://doi.org/10.1080/19425120.2010.549047

BioOne Complete (complete.BioOne.org) is a full-text database of 200 subscribed and open-access titles in the biological, ecological, and environmental sciences published by nonprofit societies, associations, museums, institutions, and presses.

Your use of this PDF, the BioOne Complete website, and all posted and associated content indicates your acceptance of BioOne's Terms of Use, available at www.bioone.org/terms-of-use.

Usage of BioOne Complete content is strictly limited to personal, educational, and non - commercial use. Commercial inquiries or rights and permissions requests should be directed to the individual publisher as copyright holder.

BioOne sees sustainable scholarly publishing as an inherently collaborative enterprise connecting authors, nonprofit publishers, academic institutions, research libraries, and research funders in the common goal of maximizing access to critical research.

Downloaded From: https://bioone.org/journals/Marine-and-Coastal-Fisheries:-Dynamics,-Management,-and-Ecosystem-Science on 29 Mar 2024
Terms of Use: https://bioone.org/terms-of-use

Marine and Coastal Fisheries: Dynamics, Management, and Ecosystem Science 3:190–218, 2011
American Fisheries Society 2011
ISSN: 1942-5120 online
DOI: 10.1080/19425120.2010.549047

ARTICLE

Quantifying Species Abundance Trends in the Northern Gulf of California Using Local Ecological Knowledge

C. H. Ainsworth*[1]
National Oceanic and Atmospheric Administration, Northwest Fisheries Science Center, 2725 Montlake Boulevard East, Seattle, Washington 98112, USA

Abstract

Ecosystem-based fisheries management requires data on all parts of the ecosystem, and this can be a barrier in data-poor systems. Marine ecologists need a means of drawing together diverse information to reconstruct species abundance trends for a variety of purposes. This article uses a fuzzy logic approach to integrate information from multiple data sources and describe biomass trends for marine species groups in the northern Gulf of California, Mexico. Forty-two species groups were analyzed, comprising fish, invertebrates, birds, mammals, turtles, and algae. The most important new data series comes from recent interviews with fishers in the northern part of the gulf. Respondents were asked to classify the abundance of various targeted and untargeted marine species groups from 1950 to the present. The fuzzy logic method integrates their responses with catch-per-unit-effort series, intrinsic vulnerability to fishing determined from life history parameters, biomass predicted by a Schaefer harvest model, and other simple indices. The output of the fuzzy logic routine is a time series of abundance for each species group that can be compared with known trends. The results suggest a general decline in species abundance across fished and unfished taxa, with a few exceptions. Information gathered from interviews indicated that older fishers tended to recognize a greater relative decrease in species abundance since 1970 than did younger fishers, providing another example of Pauly's (1995) shifting cognitive baselines.

Resource managers face an expanding array of challenges in the northern Gulf of California, Mexico. The area has ecological significance as a biodiversity "hotspot" with a high degree of endemism in fish (Gilligan 1980; Enriquez-Andrade et al. 2005), invertebrates (Brusca 2006; Hendrickx 2007), and plants (Felger 2000), and it contains critical habitat for migratory and endangered species (Velarde and Anderson 1994; Jaramillo-Legorreta et al. 2007; Lercari and Chávez 2007). Unfortunately, marine conservation is often at odds with the fisheries that are so critical to the economic and food security of coastal communities (Guerroero-Ruíz et al. 2006; Lluch-Cota et al. 2007). Agriculture, aquaculture, ecotourism, and other marine-use sectors also continue to grow and compete with fisheries for space and resources.

Some have advocated ecosystem-based fisheries management (EBFM) as an integrated approach to managing human activities and a means of reconciling human needs with those of the natural system (Garcia et al. 2003; Pikitch et al. 2004). However, EBFM is broad by definition, and quantitative tools and analyses meant to support EBFM decisions can have large data requirements; this has proved to be a barrier to implementation of management decisions (Frid et al. 2006). Deficiency in scientific survey information is most evident in developing tropical and subtropical nations like Mexico, where species diversity is high and food web dynamics are complex, yet resources for stock assessment and monitoring are scarce (Silvestre and Pauly 1997). Here, there is a need for systematized information on species abundance (Lluch-Cota et al. 2007),

Subject editor: Kenneth Rose, Louisiana State University, Baton Rouge, Louisiana, USA

*Corresponding author: cameron.ainsworth@noaa.gov
[1]Present address: Marine Resources Assessment Group Americas, 2725 Montlake Boulevard East, Seattle, Washington 98112, USA.
Received February 18, 2010; accepted August 21, 2010

Downloaded From: https://bioone.org/journals/Marine-and-Coastal-Fisheries:-Dynamics,-Management,-and-Ecosystem-Science on 29 Mar 2024
Terms of Use: https://bioone.org/terms-of-use

particularly time series data, to support ecological modeling and other endeavors.

To patch together the history of marine populations it is sometimes necessary to draw on unconventional sources of information. One useful and largely untapped resource is the local ecological knowledge (LEK) held by fishers and community members (Johannes et al. 2000). Although there are many examples in which LEK has been collected and used for study and management purposes, there are few examples in which such data are used quantitatively. Previous publications have used LEK to define species ranges (Gerhardinger et al. 2009). Some have applied statistical models to identify critical population declines (Turvey et al. 2009) or even estimate species abundance in terrestrial (Anadón et al. 2009) and marine systems (Ainsworth et al. 2008). Local ecological knowledge offers some important advantages over other types of scientific data: it is inexpensive to collect, it can be pertinent to a wide range of species, and it can inform our understanding of ecosystem changes over long time periods and wide geographic ranges. The data also reveal how the fishing industry perceives the resource and resource supply. This is a useful perspective for understanding fisher's motives and using the LEK data in applications.

This article presents the results from a series of LEK interviews recently conducted in the northern Gulf of California. The interviews help identify changes in the marine ecosystem from 1950 to the present as perceived by artisanal fishers. Considered in this study is whether the information conveyed by fishers is affected by their reliance on stocks for food and livelihood and whether younger and older fishers perceive ecosystem changes differently. Specifically, the analysis looks for evidence of the psychosocial phenomenon called shifting cognitive baselines (Pauly 1995), in which each generation of resource users accepts a lower standard as normal and so does not have an accurate appreciation of the true magnitude of historical resource decline.

The abundance trends from the LEK data are combined with five other data series developed here (simple stock size and fishery indicators) to produce composite trends detailing the likely changes in relative abundance for 42 species groups in the northern Gulf of California. The intention is that these time series for fish, invertebrates, mammals, birds, and reptiles will be useful in a variety of quantitative EBFM applications, including ecosystem modeling. A fuzzy logic algorithm (Zadeh 1965; Bellman and Zadeh 1970) is used here as a method of deriving numerical trends from ordinal LEK data, standardizing the various data streams, and combining them into a composite time series while resolving disagreements according to a transparent-rule matrix.

METHODS

Six data series are developed here and then integrated using a fuzzy logic system in order to reconstruct species abundance trends. Three series can be considered directly representative of species abundance, and the other three relate to the exploitation trends of fisheries. The abundance indicators are (1) species abundance trends from LEK interviews, (2) a catch-per-unit-effort (CPUE) series compiled from published and unpublished literature that represents relative species abundance over time, and (3) a separate yes/no indicator from LEK interviews corresponding to whether fishers had noticed a stock depletion during their careers. The exploitation indicators include (4) biomass predictions from a simple Schaefer (logistic growth) harvest model, (5) a measure of species groups' vulnerability to fishing, and (6) a yes/no indicator from LEK interviews corresponding to whether fishers had noticed a reduction in animal body size. Two parallel analyses are conducted and compared, one processing the abundance indicators and one processing the exploitation indicators. The next section explains the development of these indicators. The fuzzy logic implementation is described later.

Indicators from LEK Interviews

Researchers interviewed 81 fishers in the towns of Puerto Peñasco, Golfo de Santa Clara, Rodolfo Campodónico, Bahia Kino, Desemboque, and Puerto Libertad (Sonora) between April and June 2008 and September 2008 and February 2009. This represents around 2% of the estimated 3,800 artisanal fishers in the northern Gulf of California (P. Turk-Boyer, Centro Intercultural de Estudios de Desiertos y Océanos [CEDO], unpublished data). Interviewees ranged in age from 20 to 89 years and had expertise in the following gear types: gill net, cast net, shrimp and finfish trawls, longline, hand line, harpoon, compressor diving, and traps. On average, respondents had 28.5 years of fishing experience. The interview forms used are available from C. H. Ainsworth.

Interviewees were asked to characterize the abundance of fish, invertebrates, mammals, birds, and reptiles into one of three categories (low, medium, or high) for each of the six decades since 1950. Species were aggregated into groups; the structure was chosen to be compatible with species-aggregated, trophic-modeling approaches for fisheries research. The format of the groups generally aggregates invertebrate species, and it represents species of commercial interest and ecological importance, such as keystone species, in more detail. A statistical test is used here to show whether fishers' perceptions of species abundance varies depending on whether or not they rely on the stock for their livelihoods. For this, respondents were divided into two pools, those that targeted a given species group and those that did not. Relative abundance trends from LEK interviews were developed for 24 species groups (Table A.1 in the appendix) for each decade and used as input in the fuzzy logic procedure.

In addition to the abundance trends, simple indicators were collected in the form of yes/no questions. The questions for each species group were whether the respondents had noticed localized depletions or extirpations of the species and whether they had noticed a reduction in average body size. The yes/no responses were obtained for 36 species groups (Table A.1). They were not recorded by decade; a single response was assumed to represent the net change over a respondent's career.

Downloaded From: https://bioone.org/journals/Marine-and-Coastal-Fisheries:-Dynamics,-Management,-and-Ecosystem-Science on 29 Mar 2024
Terms of Use: https://bioone.org/terms-of-use

Catch per Unit Effort

Catch-per-unit-effort trends were determined based on CPUE or catch-and-effort data from Mexican government statistics (Diario Oficial de la Federación 2004, 2006 [see Table A.2]; CONAPESCA 2009). Additional information was obtained from unpublished statistics (V. M. Valdéz-Ornelas and E. Torreblanca, Pronatura Noroeste). Data from a concurrent study to estimate unreported catch provided port-level information (S. Perez-Valencia, CEDO, unpublished data), while a study of fishery logbooks also provided high-quality information for a small number of vessels (J. Torre and M. Rojo, Comunidad y Biodiversidad, unpublished data). Finally, the remaining data gaps were filled by other literature sources listed in Table A.2.

Catch data for major commercial species were taken from Diario Oficial de la Federación (2004, 2006) and CONAPESCA (2009), while the unpublished information, surveys, logbooks, and literature sources provided estimates of catch for minor targets and bycatch species. Where statistics were available by state, total catch in the northern gulf was assumed equal to that of Sonora and Baja California combined. The catch values also include estimates of unreported catch and discards, which are largely based on expert opinion (L. E. Calderón-Aguilera, Centro de Investigación Científica y de Educación Superior de Ensenada, personal communication). Effort trends in artisanal fisheries were based on the number of vessels operating (Galindo-Bect 2003); this approach has the advantage that it can capture trends for unregistered vessels, which may constitute as much as one-third of the fleet, judging by recent aerial surveys (Rodríguez-Valencia et al. 2008). Other effort series were located for lobsters (Vega-Velásquez 2006), small pelagic organisms (Arreguín-Sánchez et al. 2006), groupers (Arreguín-Sánchez et al. 2006), totoaba *Totoaba macdonaldi* (Lercari and Chávez 2007), and shrimp (Galindo-Bect 2003). As a last resort, effort was based on human population growth rate in two Sonoran cities, Puerto Peñasco and San Felipe (INEGI and Government of Sonora 2008a, 2008b). Catch and effort references are listed in Table A.2. Full documentation of development of catch, effort, and CPUE series is available from the author (cameron.ainsworth@noaa.gov). The CPUE series were developed for 34 species groups (Table A.1) as annual trends (units vary) and averaged to the decade level for input into the fuzzy logic procedure.

Harvest Model

A logistic growth model with harvests provides biomass (B) estimates at each year t, as in equation (1) (Schaefer 1954; Hilborn and Walters 1992),

$$B_t = B_{t-1} + r B_{t-1}\left(1 - \frac{B_{t-1}}{K}\right) - C_{t-1}. \qquad (1)$$

Catch (C) was obtained from the assembled catch series (Table A.2). The carrying capacity of the ecosystem (K) was assumed to be the unfished biomass (B_0) estimated by Lozano-Montes (2006) and Lozano-Montes et al. (2008). The B_0 values are highly uncertain, but they cover a large number of data-poor species and represent the best available estimates. The intrinsic rate of population increase (r) was estimated according to the equation $r = 4\text{MSY}/B_0$. Where possible, the maximum sustainable yield (MSY) was taken from Mexican stock assessments (Diario Oficial de la Federación 2004, 2006; Table A.2). In the absence of species distribution data, the MSY for the northern Gulf of California was assumed to be equal to the MSY values for Sonora and Baja California combined. In some cases, only values for Sonora were available, and these were inflated 20% to account for missing areas. Where the MSYs referred to Pacific Ocean stocks, the MSYs for gulf stocks were assumed to be similar on a per-area basis (the stock area was assumed to be 10% for pelagic species and 20% for other species in the gulf). If MSY estimates were not available, r was estimated using the empirical formula of Pauly (1984), that is,

$$r \approx 9.13\bar{W}^{-0.26},$$

where $\bar{W}$ is mean body weight, approximated as $\bar{W} = (W_{\max} + W_m)/2$ (Pauly 1984), with $W_{\max}$ = maximum weight and W_{m} = weight at maturity. These weight data were collected from FishBase (references provided in Tables A.3, A.4).

The model was initialized at 1950 using B_0 and run to 2008, calculating annual biomass estimates B_t in t/km^2. These were then averaged to produce decadal values ($B_{1950}, B_{1960}, \ldots, B_{2000}$) and used as inputs to the fuzzy logic algorithm. Series were developed for 26 species groups (Table A.1). Between averaging these biomass values over decades, using fuzzy sets to describe them, and combining these estimates with other abundance series, the method presented here should be insensitive to the large uncertainties involved in these calculations.

Vulnerability Index

As a final indicator of species abundance, the relative vulnerability to fishing of each exploited species group is estimated based on the method of Cheung et al. (2005). Those authors combined life history characteristics, including maximum length, the Von Bertalanffy growth constant, maximum age, fecundity, age at first maturity, and natural mortality, in a fuzzy logic framework to produce a composite vulnerability-to-fishing score. The index was shown empirically to predict species status better than common alternative proxies. Their method was recreated here. Life history information for Gulf of California species was taken from FishBase and other sources (see Tables A.3, A.4); then, using the published membership functions and expert rule set, the data were collated to produce a final vulnerability score for each species in a procedure analogous to the one described in this article. The only notable difference between this treatment and the one by Cheung et al. (2005) is that the geographic range of a species was not considered as an indicator of vulnerability because it is not relevant when considering a localized area like the Gulf of California. The vulnerability scores were calculated for individual species and averaged to the level of species groups. The available life history data allowed the

Downloaded From: https://bioone.org/journals/Marine-and-Coastal-Fisheries:-Dynamics,-Management,-and-Ecosystem-Science on 29 Mar 2024
Terms of Use: https://bioone.org/terms-of-use

calculation for 21 species groups (Table A.1). The scores are time independent, and so the same score is used for each decade in the analysis.

Fuzzy Logic Overview

Fuzzy set theory, also called fuzzy logic (Zadeh 1965; Bellman and Zadeh 1970), emulates an expert's judgment by combining inputs through a heuristic IF–THEN rule matrix to reach a conclusion regarding the data. It is a means of computing with words (Zadeh 1999), where "linguistic variables," representing a wide range of possible data types, combine according to relationships similar to "rules of thumb" contained in a rule matrix. However, where classical logic requires that a variable be categorizable into a single class (e.g., a Boolean variable belonging exclusively to a yes or no category), the linguistic variables in a fuzzy set can hold varying degrees of membership in multiple classes. For example, if "purple" is a fuzzy set that describes all colours composed of red and blue light, then indigo, violet, and fuchsia could be said to hold increasing membership in the "red" category relative to the "blue."

A Worked Example

A simple example (Figure 1), in which two data streams (abundance from interviews and CPUE) are combined to produce relative abundance, demonstrates the fuzzy logic procedure. The procedure begins by assigning an analog abundance indicator (x), such as the abundance score derived from interviews (Figure 1A). The analog indicator is then translated into fuzzy sets containing several linguistic abundance categories (Figure 1B). In the case of abundance from interviews, there are five categories ranging from low to high. The partial membership (μ) in each abundance category (n) is determined by consulting membership functions. The membership function $\mu_n(x) \in [0, 1]$ describes the degrees of membership of x in linguistic categories 1 though N, where $\Sigma_n\ \mu_n(x) = 1$. Piecewise linear membership functions are used for simplicity throughout this study.

Membership in the linguistic variable categories determines what rules operate (or "fire") in the rule matrix. In this paper, the strength at which the rules fire is determined by the algebraic sum of the intersecting memberships (Figure 1C). Many conclusions may be reached simultaneously (Figure 1D) with varying degrees of belief (firing strengths). Each time a cell in the rule matrix fires, it strengthens our belief in the corresponding conclusion. There are 50 different possible conclusions. Numbered 1 to 50, each conclusion represents a linear interpretation of abundance, so that a conclusion of 40 indicates twice the abundance of one numbered 20. Whenever a cell is fired, the partial membership that elicited that action is added to a running total for the corresponding conclusion category (Figure 1E). In this way, conclusions reached repeatedly (or fired with large partial memberships) will accrue a high score.

After all the information is passed through the matrix for a certain group–period combination, we are left with an array of 50 elements; the partial memberships in each category represent our relative confidence, or degree of belief, in that abundance conclusion. The partial memberships are normalized as in Figure 1F, after which they are passed as inputs to the defuzzification membership function (Figure 1G). Defuzzification is the process by which partial memberships are converted to a single

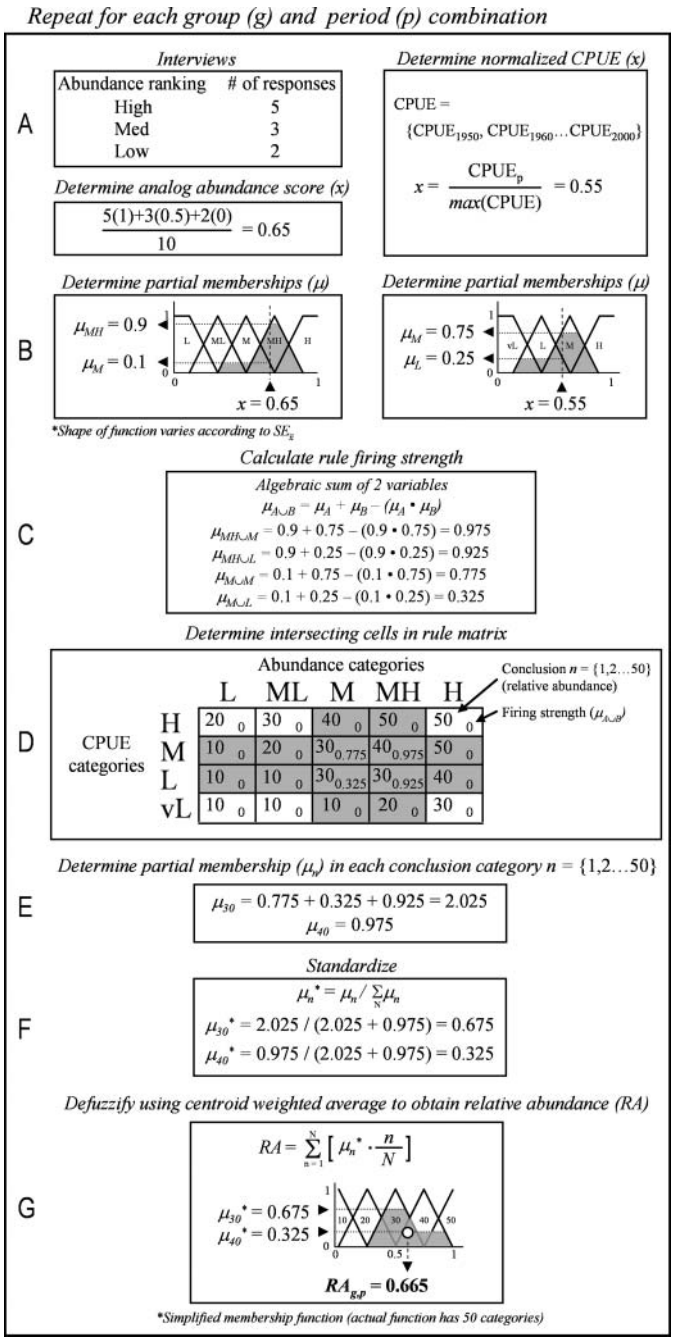


FIGURE 1. A worked example of the fuzzy logic method. A two-dimensional analysis is presented for clarity; it processes two data streams, abundance from interviews and CPUE (values are hypothetical). The algorithm presented here is repeated for each species group and time period.

Downloaded From: https://bioone.org/journals/Marine-and-Coastal-Fisheries:-Dynamics,-Management,-and-Ecosystem-Science on 29 Mar 2024
Terms of Use: https://bioone.org/terms-of-use

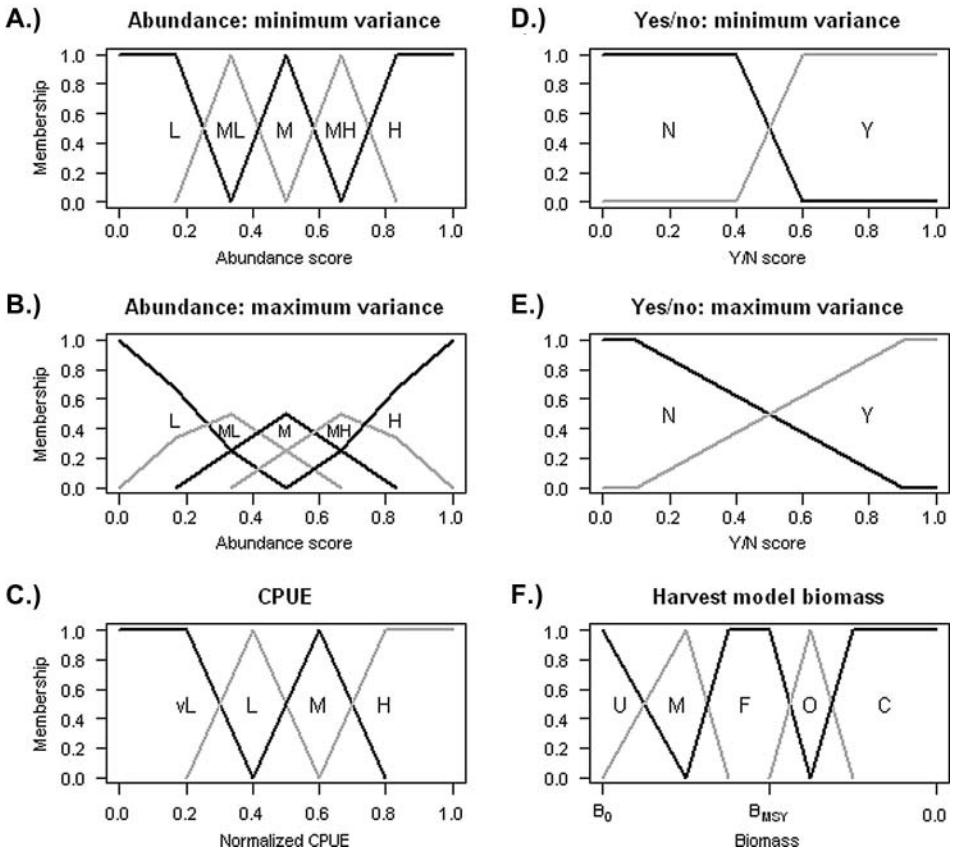


FIGURE 2. Fuzzy set membership functions. These relationships convert an analog indicator of abundance (*x*-axis) to partial memberships in linguistic abundance categories (*y*-axis). The partial memberships sum to 1 and represent the degree of belief in the abundance categories. Panels **(A)** and **(B)** show the membership in abundance categories under minimum and maximum variance between interview scores (low [L], medium–low [ML], medium [M], medium–high [MH], and high [H]); panel **(C)** shows the membership in CPUE categories (very low [vL], low [L], medium [M], and high [H]); panels **(D)** and **(E)** show the membership in yes/no (Y/N) categories under minimum and maximum variance between interview scores; and panel **(F)** shows the membership in biomass categories predicted by the harvest model (underexploited [U], moderately exploited [M], fully exploited [F], overexploited [O], and critically overfished [C]).

number representing relative abundance (i.e., a "crisp" number that is no longer part of a fuzzy set). It is therefore the reverse of the procedure described earlier to calculate memberships (i.e., Figure 1B). The defuzzification function in Figure 1G is a simplification; the actual one employed has 50 categories with triangular functions. The centroid-weighted average method of Cox (1999) is used, in which we multiply the centroid of each category (0.02, 0.04, 0.06, . . . , 1.00) by the relative weighting (or confidence) in that conclusion to obtain a weighted average between 0 and 1 that represents the relative abundance for that species group and period.

Fuzzy logic implementation.—In the worked example, the rule matrix uses two dimensions (i.e., abundance and CPUE in Figure 1D). Scaling up, the implementation for both abundance and exploitation indicators uses three dimensional matrices. The next section describes the membership functions used to characterize the six data series involved. Later, combinatorial rules, the rule matrices, and defuzzification are discussed.

Membership functions.—The abundance information obtained in interviews was evaluated according to the membership functions in Figure 2A, B. The *x*-axis in Figure 2A, B represents the analog abundance (x) score obtained from the interviews. It is averaged across respondents, "low" responses being assigned a value of 0, "medium" ones being assigned 0.5, and "high" ones being assigned 1.0. An average abundance score of 0.5 could be achieved through (at least) two scenarios: one in which every fisher reported medium abundance and one in which half of the fishers reported high abundance and half reported low abundance. To account for agreement between respondents, a dynamic membership function was used in which the angle subtended by the triangular functions increases from a minimum (Figure 2A) to a maximum (Figure 2B) if there was high or low agreement between respondents, respectively.

As a measure of agreement, the standard error of the mean was determined for each group–period combination as $SE_{\overline{X}} = \sigma^2/n$, where n is the number of respondents. Variance (σ^2) was calculated assuming a binomial distribution in which the majority response category (low, medium, or high) was considered "correct" and all other responses were considered "incorrect"; thus $\sigma^2 = np(1-p)$, where p is the fraction of correct responses.

Downloaded From: https://bioone.org/journals/Marine-and-Coastal-Fisheries:-Dynamics,-Management,-and-Ecosystem-Science on 29 Mar 2024
Terms of Use: https://bioone.org/terms-of-use

Using the $SE_{\overline{X}}$ in this way corrects for the varying number of respondents per decade (e.g., fewer people contributed to the 1950s estimates than to the 2000–2009 estimates). The $SE_{\overline{X}}$ was next standardized so that the group–decade combination that had the best agreement (lowest error) adopted the membership function in Figure 2A, that with the poorest agreement adopted the function in Figure 2B, and other responses adopted intermediate functions, where slopes and intercepts were scaled linearly between the extremes.

Membership was evaluated in each of five fuzzy set abundance categories: low (L), medium–low (ML), medium (M), medium–high (MH), and high (H). Categories L and H use trapezoidal forms: beyond a certain threshold, full membership was assigned to these extreme categories. This allowed us to ignore the influence of a small number of responses that contradict the majority belief. Although the level of fishing effort, fishing skill, gear efficiency, catchability, and other factors will affect the amount of catch a fisher obtains for any given level of fish abundance, this methodology trusts that fishers can integrate over a wide range of externalities and thus have valid cognitive models of resource supply. Averaging their responses to obtain x should also eliminate many possible biases. For this reason, we restricted the analysis to consider only group–period combinations that had at least eight respondents.

The membership function used to categorize (normalized) CPUE per species group and decade is provided in Figure 2C. It categorizes the analog CPUE score into four linguistic categories: very low (vL), low (L), medium (M), and high (H). The membership functions used to categorize "yes/no" depletion and body size indicators into yes (Y) and no (N) categories again use a dynamic membership function to reflect the level of agreement between respondents (Figure 2D, E). As with the abundance indicators from interviews, the form of the membership function varies according to $SE_{\overline{X}}$, which was calculated assuming a binomial distribution of yes and no answers. The membership function used to evaluate biomass predictions from the logistic harvest model is provided in Figure 2F. Here, membership is evaluated in five linguistic categories: overexploited (O) or critically overfished (C) if the decadal biomass value (e.g., B_{1950}, B_{1960},. . ., B_{2000}) was below B_{MSY}, or underexploited (U), moderately exploited (M), or fully exploited (F) if biomass was above B_{MSY}. In the case of the Cheung et al. (2005) vulnerability index, our input membership function is identical to their output (defuzzification) membership function; it is equivalent to Figure 2C with four linguistic categories: low (L), medium (M), high (H), and very high (vH).

Combining the data series.—Having determined the partial memberships in linguistic categories through the use of membership functions, we next consult the rule matrices to combine the information; Tables 1A and 1B show the abundance and exploitation matrices, respectively.

Membership in the three indicators (on X, Y, and Z axes of each matrix) leads us to a conclusion regarding the abundance for each species in each time period. The conclusions are found inside the matrix cells (color coded in Table 1). Each cell fires with a strength proportional to the algebraic sum of the intersecting memberships. All axes are assumed to be independent, and the strength of memberships is combined using the probability-OR operator for three variables, namely,

$$\mu_{A\cup B\cup C} = \mu_A + \mu_B + \mu_C - (\mu_A \cdot \mu_B) - (\mu_A \cdot \mu_C) - (\mu_B \cdot \mu_C) + (\mu_A \cdot \mu_B \cdot \mu_C), \quad (2)$$

where $\mu_{A\cup B\cup C}$ is representative of our degree of belief in the corresponding conclusion. This fuzzy union operator was used based on the algebraic sum rather than the alternative union operator (μ_A OR μ_B OR $\mu_C = \max[\mu_A, \mu_B, \mu_C]$) or fuzzy intersection operator (μ_A AND μ_B AND $\mu_C = \min[\mu_A, \mu_B, \mu_C]$) used by previous authors (Cheung et al. 2005; Ainsworth et al. 2008) so that all operands contribute something to the output; the algorithm is thus useful for a wider range of data availabilities (see Table A.1).

Various parts of the rule matrix were accessed for each time period (1950, 1960, 1970, 1980, 1990, and 2000). If the value of the depletion indicators (i.e., stock depletion or body size reduction) is "yes," this has the effect of lowering the relative abundance score of the conclusion for recent periods (1980 to 2000) but increasing the abundance score of the conclusion for older periods (1950 to 1970) (i.e., the slope between 1950 and 2000 becomes more negative; Table 1). Matrices for the intermediate periods (1960, 1970, 1980, and 1990) are not shown, but they apply a smooth linear transition between the extreme values in 2000 (top row of Table 1) and 1950 (middle row of Table 1). If the value of the depletion indicator is "no," then the bottom row of Table 1 is accessed regardless of decade.

After all data series pass through the matrix, we are left with 50 different abundance conclusions with varying degrees of belief (partial memberships), as described in the worked example. The partial memberships are combined through defuzzification and are converted to a single crisp number representing the relative abundance. This process is repeated for each species group and period to produce time series of relative abundance that can be compared with observational series (Table 2).

Summary.—The data series used here for abundance indicators consisted of decadal abundance trends from LEK interviews, annual CPUE data averaged to decades, and a yes/no population-level depletion indicator from LEK interviews that referred to all decades. The data series used for the exploitation indicators consisted of annual stock biomass from a logistic growth harvest model averaged to decades, a vulnerability-to-fishing index that referred to all decades, and a yes/no body size change indicator from LEK interviews that referred to all decades. These numerical indicators were translated into memberships in ordinal linguistic categories (e.g., low, medium, or high) using membership functions, where membership in each category represents our relative belief in that category's being true. The memberships in each category determined the firing

Downloaded From: https://bioone.org/journals/Marine-and-Coastal-Fisheries:-Dynamics,-Management,-and-Ecosystem-Science on 29 Mar 2024
Terms of Use: https://bioone.org/terms-of-use

TABLE 1. Heuristic rule matrices used by the fuzzy logic algorithm to combine data sources. Two parallel matrices deal with abundance and exploitation indicators, respectively. Abundance indicators include abundance estimated by interviews, catch per unit effort (CPUE) estimated from literature values, and stock depletion suggested by interviews. Exploitation indicators include exploitation status suggested by the Schaefer harvest model, vulnerability to fishing based on life history characteristics, and body size reduction suggested by interviews. The conclusions resulting from these *X*–*Y*–*Z* linguistic variables are identified in the cells. They represent a linear abundance index that ranges from 1 to 50. The presence of depletion or size-reduction indicators upgrades the abundance conclusion for past periods (e.g., 1950) and downgrades it for recent periods (e.g., 2000). Matrices for the intermediate periods (1990, 1980, 1970, and 1960; not shown) apply a smooth transition between the extremes 2000 and 1950. Abbreviations are as follows: L = low, ML = medium–low, M = medium, MH = medium-high, H = high, vL = very low, vH = very high, C = critically overfished, O = overexploited, F = fully exploited, M = moderately exploited, u = underexploited, Y = yes, and N = no.

(A) Abundance indicators

Evaluation period		Abundance from interviews					Depletion?
		L	ML	M	MH	H	
2000	CPUE H	20	30	40	50	50	Y
	CPUE M	10	20	30	40	50	
	CPUE L	10	10	20	30	40	
	CPUE vL	10	10	10	20	30	
1950	CPUE H	40	50	50	50	50	Y
	CPUE M	30	40	50	50	50	
	CPUE L	20	30	40	50	50	
	CPUE vL	10	20	30	40	50	
ALL	CPUE H	30	40	45	50	50	N
	CPUE M	20	30	40	45	50	
	CPUE L	15	20	30	40	45	
	CPUE vL	10	15	20	30	40	

(B) Exploitation indicators

		Harvest model exploitation					Size reduction?
		C	O	F	M	U	
2000	Vulnerability L	20	30	40	50	50	Y
	Vulnerability M	10	20	30	40	50	
	Vulnerability H	10	10	20	30	40	
	Vulnerability vH	10	10	10	20	30	
1950	Vulnerability L	40	50	50	50	50	Y
	Vulnerability M	30	40	50	50	50	
	Vulnerability H	20	30	40	50	50	
	Vulnerability vH	10	20	30	40	50	
ALL	Vulnerability L	30	40	45	50	50	N
	Vulnerability M	20	30	40	45	50	
	Vulnerability H	15	20	30	40	45	
	Vulnerability vH	10	15	20	30	40	

strength of cells in a rule matrix, where each cell leads to a particular conclusion regarding species abundance. Finally, a crisp abundance score was determined through defuzzification, the reverse of the process that created the membership scores from the numerical indicators. Abundance per decade is plotted for each species group, representing its stock status since 1950.

RESULTS

For many species groups, the respondents in the LEK interviews were likely to indicate high biomass in the 1950s and low biomass in 2000–2009 (Figure 3). The trends are not often monotonic and there are conspicuous exceptions, like pinnipeds and seabirds. For these groups, the respondents were more likely to indicate high biomass in recent years. For pinnipeds, this conflicts with known population trends in the Gulf of California as a whole (Szteren et al. 2006; Wielgus et al. 2008). However, census data suggest that California sea lion *Zalophus californianus* rookeries in the north, where interviews occurred, may have seen population increases since the early 1990s (Szteren et al. 2006). The status of seabird populations in the gulf is poorly known from scientific studies (Palacios and Alfaro 2005).

Comparing the abundance scores offered by people who depend on the resource economically with the scores from those who do not revealed no significant difference for any species in responses for the 2000 period (two-tailed Mann–Whitney *U*-test: $P > 0.05$). This held true for all 15 species groups tested (i.e., all exploited fish and invertebrate species; minimum sample size = 6). This suggests that fishers offered an unbiased view regardless of whether or not they depend on the stock for their livelihood, and being specialized in catching a certain type of animal did not improve or alter their assessment relative to that of a "nonexpert" fisher.

When asked to characterize the abundance of species groups for the decades between 1950 and the present, fishers showed the most agreement for the earliest decade, the 1950s (Figure 4). They generally agreed that abundance was high during this period (irrespective of the species group). Each subsequent decade had less agreement, except for the most recent decade, 2000, in which interviewees tended to agree that abundances were low. This pattern was consistent across species groups, with a few exceptions.

Downloaded From: https://bioone.org/journals/Marine-and-Coastal-Fisheries:-Dynamics,-Management,-and-Ecosystem-Science on 29 Mar 2024
Terms of Use: https://bioone.org/terms-of-use

TABLE 2. Taxa included in the current study and those in previous studies estimating abundance and biomass trends in the northern Gulf of California.

Functional group	Species in source material	Type of information	Reference
Blue crab	Arched swimming crab *Callinectes arcuatus*, blue swimming crab *C. bellicosus*	Relative biomass	INP (2006)
Blue shrimp	Blue shrimp *Litopenaeus stylirostris*	CPUE	Galindo-Bect et al. (2000)
Crabs and lobsters	Spiny lobsters (*Panulirus interruptus*, *P. inflatus*, *P. gracilis*)	CPUE	INP (2006)
Groupers and snappers	Snapper *Lutjanus* spp., barred pargo *Hoplopagrus guntherii*	CPUE	INP (2006)
Herbivorous echinoderms	Red urchin *Strongylocentrotus franciscanus*	Biomass	INP (2006)
Large pelagic sharks	Large sharks *Carcharhinus* spp., *Alopias* spp., scalloped hammerhead *Sphyrna lewini*, whitenose shark *Nasolamia velox*	CPUE	INP (2006)
Penaeid shrimp	Brown shrimp *Penaeus californiensis*, blue shrimp *P. stylirostris*, and white shrimp *P. vannamei*	CPUE	Magallon-Barajas (1987)
Pinnipeds	California sea lion *Zalophus californianus californianus*	Relative biomass	Szteren et al. (2006)
Small pelagics	Small pelagics (Pacific sardine *Sardinops sagax caeruleus,* herrings *Opisthonema* spp., Pacific chub mackerel *Scomber japonicus*, anchoveta *Cetengraulis mysticetus*, round herring *Etrumeus teres*, leatherjacks *oligoplites* spp., northern anchovy *Engraulis mordax*)	CPUE	INP (2006)
Squid	Jumbo squid *Dosidicus gigas*	Relative biomass	Nevárez-Martínez et al. (2006)
Totoaba	Totoaba *Totoaba macdonaldi*	Biomass	Larcari and Chavez (2007)

Analyzing only the remarks from the interviewees concerning species abundance, we found that older fishers tended to recognize a greater degree of population decline since 1970 than did younger fishers (Figure 5). We considered the time since 1970 rather than that since 1950 in order to include a greater number of respondents. All species groups tested are aggregated into the six categories shown in Figure 5. The relationship between fisher age and reported abundance change is significant for mammals, other fish, turtles, and invertebrates, weakly significant for reef fish, and nonsignificant for birds (F-test). However, the results are not significant when we contrast the perceived decline against the number of years of fishing experience rather than fishers' ages: reef fish ($P = 0.087$), mammals ($P = 0.35$), birds ($P = 0.31$), other fish ($P = 0.18$), turtles ($P = 0.012$), and invertebrates ($P = 0.51$). Trusting the cognitive model of stock abundance held by older fishers (those above the median age of 43) produces a much different result in the hindcasted abundance trends resulting from the fuzzy logic routine than trusting that of the younger fishers (Figure A.1). However, the differing opinions of these groups provide a range of plausible trajectories for relative abundance over time. The discrepancy is most noticeable in targeted and charismatic species.

The method of Cheung et al. (2005) provides an estimate of vulnerability to fishing based on life history patterns (Figure 6). Elasmobranchs, which tend to be long-lived and late maturing and have low fecundity, show the greatest overall vulnerability. This is consistent with their known biology (Stevens et al. 2000; Sadovy 2001) and the history of exploitation in the northern Gulf of California (Bizzarro et al. 2009). Also vulnerable are reef fish species, in particular, large-bodied piscivores that aggregate during breeding, such as the species included in the "groupers and snappers" group and the "large reef fish" group (Musick et al. 2000).

Crisp outputs of the fuzzy logic algorithm suggest that many species groups have suffered some degree of depletion since 1950 (Figure 7). There is satisfactory agreement between outputs from the abundance indicators and the exploitation

Downloaded From: https://bioone.org/journals/Marine-and-Coastal-Fisheries:-Dynamics,-Management,-and-Ecosystem-Science on 29 Mar 2024
Terms of Use: https://bioone.org/terms-of-use

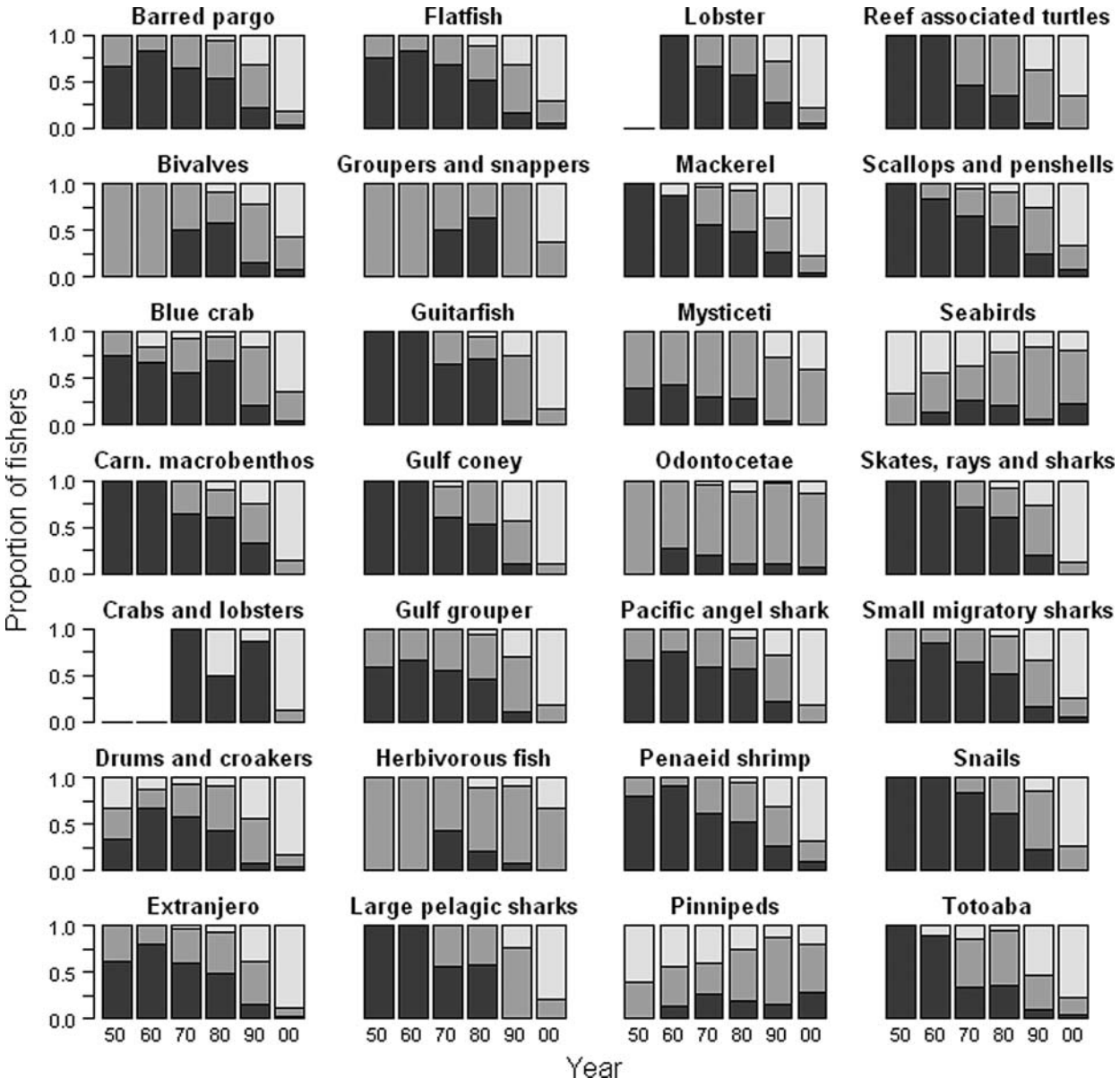


FIGURE 3. Actual interview results, presented as the proportions of fishers reporting high (dark gray), medium (medium gray), and low biomass (light gray) for each species group and time period (50 = the 1950s and so forth). Species groups that had at least eight respondents are shown. The composition of the groups is given in Table A.5 in the appendix.

indicators. Groups that show serious discrepancy between these two series are pinnipeds and blue shrimp; all other groups achieved at least a qualitative similarity. The trend based on exploitation indicators suggests that pinniped numbers have decreased; this conclusion is largely based on a perceived body size decrease by interviewees. However, the trend based on abundance indicators suggests an increase for these animals, reflecting the source interview results mentioned earlier (see Figure 3). In the case of blue shrimp, the exploitation indicators suggest a steady depletion of the stock, a result also suggested by the harvest model. However, the population trend signified by the abundance indicators suggests that the abundance increased from 1950 to 1980 and subsequently declined. This shows the influence of the CPUE series. The initial increase in CPUE may reveal population changes, or it may reflect the introduction of modern fishing methods that increased fishing efficiency. For both pinnipeds and blue shrimp, previously published abundance series support the apparent increase in abundance proffered by the abundance indicators and discredit the decrease in abundance proffered by the exploitation indicators. The abundance indicators consistently agree with the direction of change suggested by the observational data.

Downloaded From: https://bioone.org/journals/Marine-and-Coastal-Fisheries:-Dynamics,-Management,-and-Ecosystem-Science on 29 Mar 2024
Terms of Use: https://bioone.org/terms-of-use

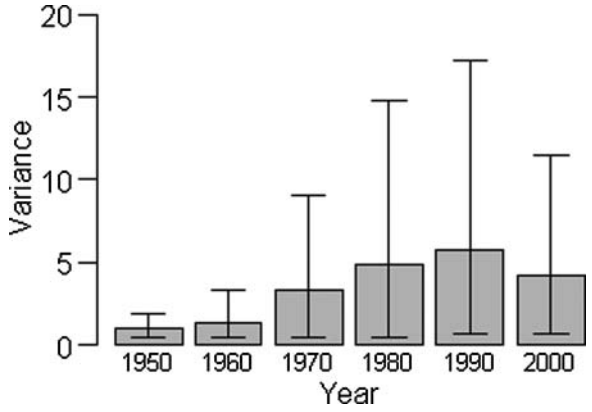


FIGURE 4. Variance among fishers' abundance scores from interviews. Variance is calculated assuming a binomial distribution (see text). Bars show the average score for all species groups analyzed; error bars show total range.

DISCUSSION

The results from interviews consistently indicated a downward trend for most populations, although this could reflect a spatial bias in reporting if fishers are referring to localized depletions in fishing areas. The interviews also were concentrated in the most heavily populated and exploited region of the gulf, which is in the northeast; this also adds a potential bias. Nevertheless, the abundance and exploitation series usually agree, which lends credence to the overall trend. In other words, the LEK data that informed the abundance trends are consistent with the catch and life history information that informed the exploitation trends. Estimates of relative biomass and abundance from previous studies tend to corroborate the fuzzy logic outputs despite a slight mismatch in species groupings and study area used. However, decreases in relative abundance (or body size) do not necessarily indicate overexploitation, as these are natural consequences of harvesting even in well-managed stocks and may be desirable (Hilborn 2007). Although the trends determined here are relative, being comparable only across species groups and between time periods, it would be possible to develop absolute trends by scaling the fuzzy logic output to match the available partial time series from scientific sampling (as in Ainsworth et al. 2008). As yet, it is not feasible to do this in the northern Gulf of California since so few groups have reliable survey information specific to the study area.

One noteworthy result is that even most untargeted species are reported by fishers to have declined. There could be psychological factors influencing this perception among fishers (Ainsworth et al. 2008); fishers' perceptions factor into both the abundance and exploitation indicators. Unfortunately, the suggestion that both predator and prey are declining may be plausible given the major ecological changes in the Gulf of California over the last century. Regulation of the Colorado River flow by numerous dams and increased freshwater consumption in the southwestern United States and Mexico has altered the marine assemblage (Rodríguez et al. 2001; Lozano-Montes

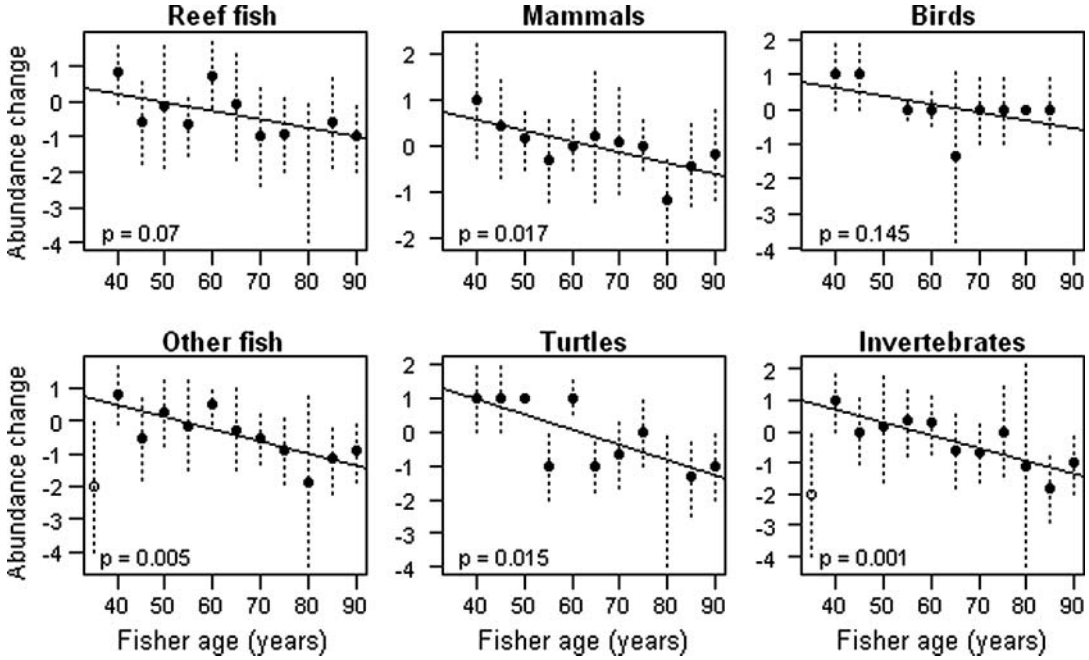


FIGURE 5. Evidence of shifting baselines in the northern Gulf of California. The *y*-axis shows the change in average perceived abundance between 1970 and 2000, the *x*-axis the age of fishers. A change of −1.0 corresponds to a reduction from high to medium or medium to low in terms of the average interview abundance score. All relationships are significant at $\alpha = 0.05$ (F-test) except those for reef fish and birds. Outliers (open circles) were removed from the data for invertebrates and other fish; error bars = SDs.

Downloaded From: https://bioone.org/journals/Marine-and-Coastal-Fisheries:-Dynamics,-Management,-and-Ecosystem-Science on 29 Mar 2024
Terms of Use: https://bioone.org/terms-of-use

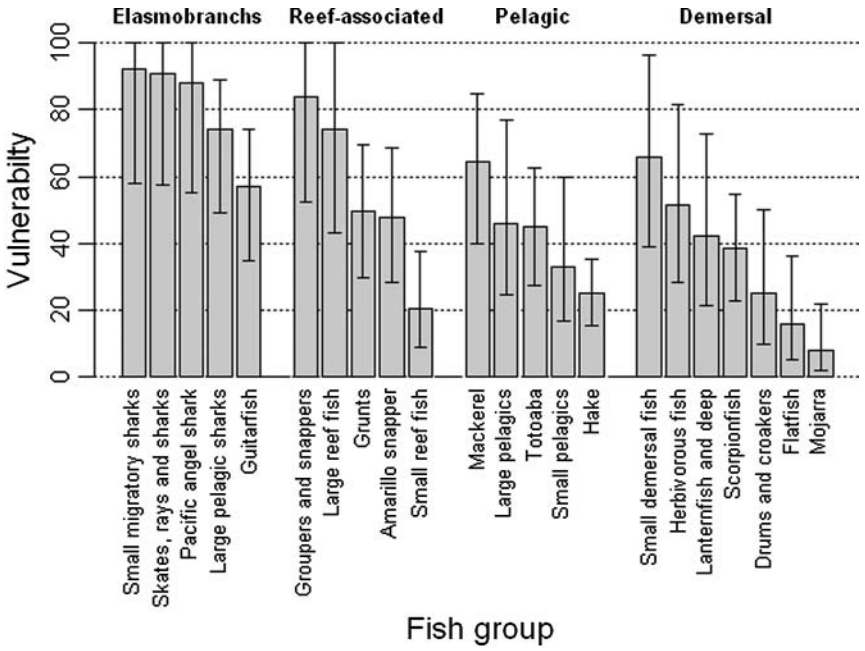


FIGURE 6. Vulnerability to fishing as predicted by the algorithm of Cheung et al. (2005) based on life history characteristics. The error bars show the upper and lower bounds of the conclusion fuzzy membership function designed by Cheung et al. and reflect the precision of their estimates based on the width of their output membership functions. The composition of the groups is given in Table A.5.

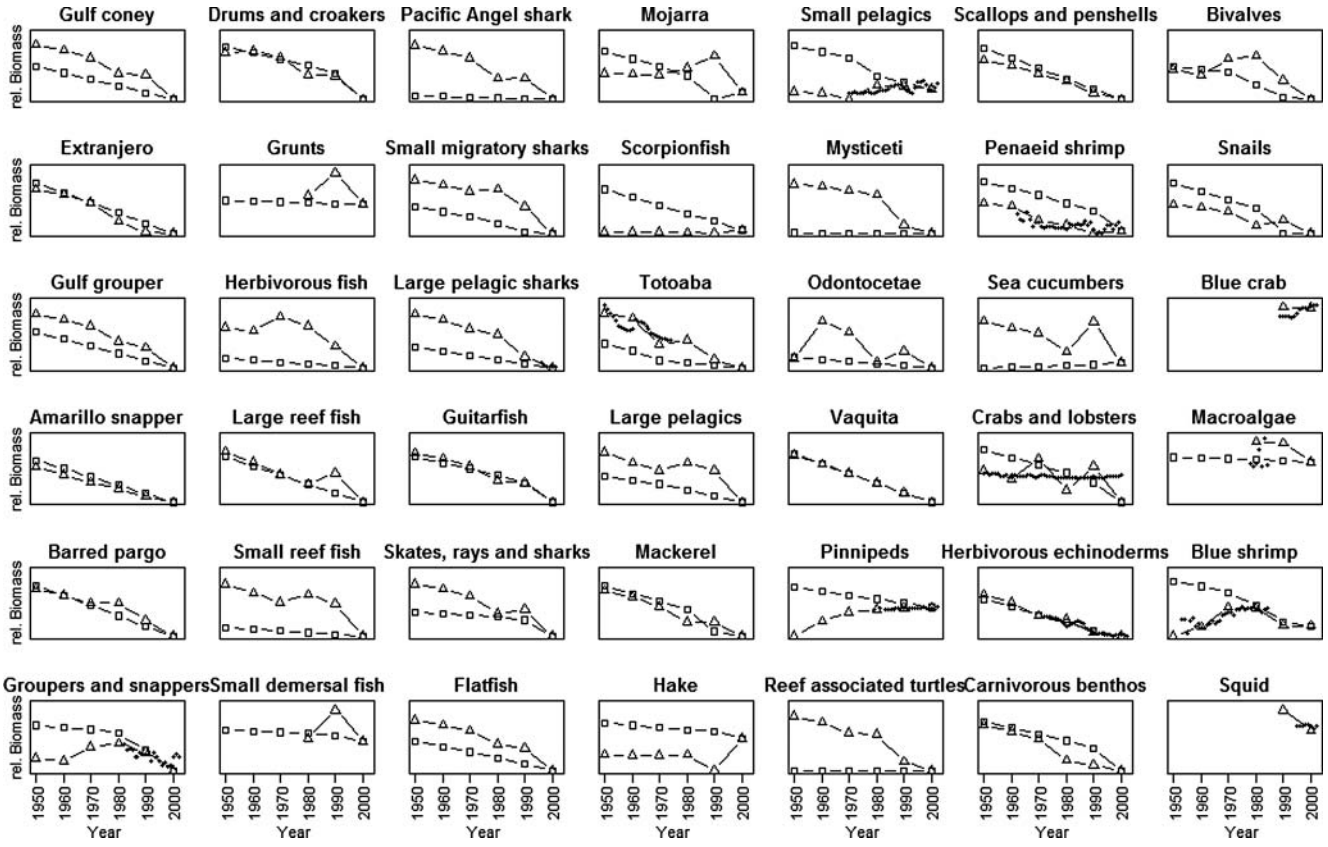


FIGURE 7. Abundance of species groups predicted by the fuzzy logic algorithm, as suggested by abundance indicators (triangles) and exploitation indicators (squares). Trends have been scaled to agree in the year 2000. Bullet points show the relative abundance trends of representative species from previous studies (Table 2); residuals are minimized with respect to abundance indicators. See Figure A.1 for the effect of respondent's age on abundance indicators. The composition of the groups is given in Table A.5.

Downloaded From: https://bioone.org/journals/Marine-and-Coastal-Fisheries:-Dynamics,-Management,-and-Ecosystem-Science on 29 Mar 2024
Terms of Use: https://bioone.org/terms-of-use

2006), affecting the salinity gradient, estuarine habitat conditions, nutrient loading, and other factors important to fish and invertebrate production (Lavín and Sanchez 1999; Galindo-Bect et al. 2000). Therefore, management of this area may consider whether forcing factors unrelated to fishing effort have had a major influence on ecosystem structure.

Even in a region like the northern Gulf of California, which is poor in scientific data, it is possible to identify which species are likely to require special attention by fishery managers with a minimal investment in effort and no regional data using Cheung et al.'s (2005) vulnerability method. In this application, life history values were averaged across all constituent species in the aggregated species groups, so the vulnerability scores in Figure 6 represent the "average" fish in each of these groups. Individual species within groups will vary in life history parameters. We may expect the most vulnerable species to decline first under fishing pressure and perhaps even to be extirpated before the group has become seriously depleted. Methods exist to predict the most vulnerable species within a species group (Cheung and Pitcher 2004). Aggregating similar species into groups is a useful convenience for generalizing fishers' perceptions, and it is necessary for many EBFM ecosystem modeling approaches in order to simplify the food web and manage data gaps (although aggregating species carries a strong set of assumptions) (Chalcraft and Resetarits 2003).

Analysis of interview results suggests that older fishers perceive a greater decline in abundance since 1970 than do younger fishers. This confirms the results of two earlier studies in the Gulf of California suggesting that the true magnitude of stock decline is not well appreciated by those who rely on the resource (Sáenz-Arroyo et al. 2005; Lozano-Montes et al. 2008). These findings add to a growing body of literature on the subject of shifting cognitive baselines. Similar studies have been conducted in many areas of the world, with consistent results that validate Pauly's (1995) premise (e.g., North America [Baum and Myers 2004], Asia [Ainsworth et al. 2008], Africa [Bunce et al. 2008], and Europe [Airoldi and Beck 2007]).

The quantitative aspects of EBFM require some ability to forecast ecosystem-level population effects, but the data requirements of EBFM models are a barrier to their use, especially in regions like the northern Gulf of California where sufficient sampling data are unavailable. The fuzzy logic technique presented here, which was adapted and improved from Ainsworth et al. (2008), can provide numerical abundance trends that substitute for formal stock assessment. The method relies heavily on qualitative information. Nevertheless, it offers a transparent, replicable, and flexible tool that can be updated as new information becomes available. The quality of outputs is still limited by the available data. For example, difficulties in applying LEK information (Brook and McLachlan 2005) or CPUE data (Beverton and Holt 1957; Hilborn and Walters 1992) still apply. In other ecosystems, available data may support the use of a more sophisticated harvest model. However, when several sources of data are combined, reliance on any one source is reduced. This work represents the first attempt to describe abundance trends for many of the species it considers. The fuzzy logic approach is flexible enough to accommodate a range of data, and it can provide marine ecologists with time series information on abundance for a variety of EBFM applications in data-limited situations.

ACKNOWLEDGMENTS

I thank the following researchers at the Centro Intercultural de Estudios de Desiertos y Océanos (CEDO, Puerto Peñasco): Mabilia Urquidi, Sandra Reyes, Hem Nalini Morzaria Luna, Abigail Iris, and Eleazar López, along with Nabor Encinas of Comunidad y Biodiversidad (Guaymas) for carrying out the interviews. The following people provided helpful discussions and review of the manuscript: Isaac Kaplan, Phil Levin, Marc Mangel, Hem Nalini Morzaria Luna, Nick Tolimieri, Jameal Samhouri (Northwest Fisheries Science Center), and William Cheung (University of East Anglia). I also thank Kenneth Rose and two anonymous referees for their careful reviews, which greatly improved the quality of the manuscript. The David and Lucille Packard Foundation provided funding for this study. The Mia J. Tegner Memorial Research Grants Program provided funding for CEDO community interviews.

REFERENCES

Ainsworth, C. H., I. C. Kaplan, P. S. Levin, R. Cudney-Bueno, E. A. Fulton, M. Mangel, P. Turk-Boyer, J. Torre, A. Pares-Sierra, and H. Morzaria-Luna. In press. Atlantis model development for the northern Gulf of California. NOAA Technical Memorandum NMFS-NWFSC.

Ainsworth, C. H., T. Pitcher, and C. Rotinsulu. 2008. Evidence of fishery depletions and shifting cognitive baselines in eastern Indonesia. Biological Conservation 141:848–859.

Airoldi, L., and M. W. Beck. 2007. Loss, status and trends for coastal marine habitats of Europe. Oceanography and Marine Biology 45:345–405.

Anadón, J. D., A. Giménez, R. Ballestar, and I. Pérez. 2009. Evaluation of local ecological knowledge as a method for collecting extensive data on animal abundance. Conservation Biology 23:617–625.

Baum, J. K., and R. Myers. 2004. Shifting baselines and the decline of pelagic sharks in the Gulf of Mexico. Ecology Letters 7:135–145.

Bellman, R. E., and L. A. Zadeh. 1970. Decision-making in a fuzzy environment management. Science (Washington, D.C.) 17:141–164.

Beverton, R. J., and S. J. Holt. 1957. On the dynamics of exploited fish populations. Ministry of Agriculture, Fisheries and Food, London.

Bizzarro, J. J., W. D. Smith, J. F. Márquez-Farías, J. Tyminski, and R. E. Hueter. 2009. Temporal variation in the artisanal elasmobranch fishery of Sonora, Mexico. Fisheries Research (Amsterdam) 97:103–117.

Brook, R. K., and S. M. McLachlan. 2005. On using expert-based science to "test" local ecological knowledge. Ecology and Society 10:3.

Brusca, R. C. 2006. Invertebrate biodiversity in the northern Gulf of California. Pages 418–504 *in* R. S. Felger and W. Broyles, editors. Dry borders: great natural reserves of the Sonoran Desert. University of Utah Press, Salt Lake City.

Bunce, M., L. D. Rodwell, R. Gibb, and L. Mee. 2008. Shifting baselines in fishers' perceptions of island reef fishery degradation. Ocean and Coastal Management 51:285–302.

Chalcraft, D. R., and W. H. Resetarits. 2003. Predator identity and ecological impacts: functional redundancy or functional diversity? Ecology (London) 84:2407–2418.

Downloaded From: https://bioone.org/journals/Marine-and-Coastal-Fisheries:-Dynamics,-Management,-and-Ecosystem-Science on 29 Mar 2024
Terms of Use: https://bioone.org/terms-of-use

Cheung, W. L., and T. J. Pitcher. 2004. An index expressing risk of local extinction for use with dynamic ecosystem simulation models. Pages 94–102 *in* T. J. Pitcher, editor. Back to the future: advances in methodology for modeling and evaluating past ecosystems as future policy goals. University of British Columbia Press, Fisheries Centre Research Reports 12(1), Vancouver.

Cheung, W. L., T. J. Pitcher, and D. Pauly. 2005. A fuzzy logic expert system to estimate intrinsic extinction vulnerabilities of marine fishes to fishing. Biological Conservation 124:97–111.

CONAPESCA (Comisíon Nacional de Acuacultura y Pesca). 2009. Anuario estadístico de acuacultura y pesca (1980–2000). [Statistical annual for aquaculture and fisheries (1980–2000).] CONAPESCA, Mazatlán, Mexico. Available: www.conapesca.sagarpa.gob.mx. (April 2009.)

Cox, E. 1999. The fuzzy systems handbook: a practitioner's guide to building, using and maintaining fuzzy systems. AP Professional, San Diego, California.

Enriquez-Andrade, R., G. Anaya-Reynam, J. C. Barrera-Guevara, M. A. Carvajal-Moreno, M. E. Martinez-Delgado, J. Vaca-Rodriguez, and C. Valdes-Casillas. 2005. An analysis of critical areas for biodiversity conservation in the Gulf of California region. Ocean and Coastal Management 48:31–50.

Felger, R. 2000. Flora of the Gran Desierto and Río Colorado of northwestern Mexico. University of Arizona Press, Tucson.

Frid, C. J., O. A. Paramor, and C. L. S. Scott. 2006. Ecosystem based management of fisheries: is science limiting? ICES Journal of Marine Science 63:1567–1572.

Galindo-Bect, M. S. 2003. Larvas y postlarvas de camarones Peneidos en el Alto Golfo de California y capturas de camarón con relacion al flujo del Río Colorado. [Larval and postlarval penaeid shrimp in the upper Gulf of California and shrimp capture in relation to the flow of the Colorado River.] Doctoral dissertation. Universidad Autonoma de Baja California, Ensenada.

Galindo-Bect, M. S., E. P. Glenn, H. M. Page, K. Fitzsimmons, L. A. Galindo-Bect, J. M. Hernandez-Ayon, R. L. Petty, J. Garcia-Hernanedez, and D. Moore. 2000. Penaeid shrimp landings in the upper Gulf of California in relation to Colorado River freshwater discharge. U.S. National Marine Fisheries Service Fishery Bulletin 98:222–225.

Garcia S. M., A. Zerbi, C. Aliaume, T. Do Chi, and G. Lasserre. 2003. The ecosystem approach to fisheries: issues, terminology, principles, institutional foundations, implementation and outlook. FAO (Food and Agriculture Organization of the United Nations) Fisheries Technical Paper 443.

Gerhardinger, L. C., M. Hostim-Silva, R. P. Medeiros, J. Matarezi, A. A. Bertoncini, M. O. Freitas, and B. P. Ferreira. 2009. Fishers' resource mapping and goliath grouper *Epinephelus itajara* (Serranidae) conservation in Brazil. Neotropical Ichthyology 7:93–102.

Gilligan, M. R. 1980. Island and mainland biogeography of resident rocky-shore fishes in the Gulf of California. Doctoral dissertation. University of Arizona, Tucson.

Guerroero-Ruíz, M., J. Urbán-Ramírez, and L. Rojas-Bracho. 2006. Las ballenas del Golfo de California. [Whales of the Gulf of California.] Secretaría de Medio Ambiente y Recursos Naturales, Instituto Nacional de Ecología, Mexico City.

Hendrickx, M. E. 2007. Biodiversidad y ecosistemas: el caso del Pacífico mexicano. [Biodiversity and ecosystems: the case of the Mexican Pacific.] Pages 116–123 *in* A. Córdova, F. Rosete-Verges, G. Enríquez, and B. Fernández de la Torre, editors. Ordenamiento ecológico marino: visión temática de la regionalización. [Marine ecological planning: thematic visions of regional implementation.] Secretaría de Medio Ambiente y Recursos Naturales, Instituto Nacional de Ecología, Mexico City.

Hilborn, R. 2007. Reinterpreting the state of fisheries and their management. Ecosystems 10:1362–1369.

Hilborn, R., and C. J. Walters. 1992. Quantitative fisheries stock assessment: choice, dynamics and uncertainty. Chapman and Hall, New York.

INP (Instituto Nacional de la Pesca). 2006. Sustentabilidad y pesca responsable en México: evaluación y manejo. [Sustainability and responsable fishing in Mexico: evaluation and management.] SAGARPA, Delegación Benito Juárez, Mexico City.

Jaramillo-Legorreta, A., L. Bojas-Bracho, R. L. Brownell, A. J. Read, R. R. Reeves, K. Ralls, and B. Taylor. 2007. Saving the vaquita: immediate action, not more data. Conservation Biology 21:1653–1655.

Johannes, R. E., M. M. Freeman, and R. J. Hamilton. 2000. Ignore fisher's knowledge and miss the boat. Fish and Fisheries 1:257–271.

Lavín, M. F., and S. Sanchez. 1999. On how the Colorado River affected the hydrography of the upper Gulf of California. Continental Shelf Research 19:1545–1560.

Lercari, D., and E. A. Chávez. 2007. Possible causes related to historic stock depletion of the Totoaba, *Totoaba macdonaldi* (Perciformes: Sciaenidae), endemic to the Gulf of California. Fisheries Research (Amsterdam) 86:136–142.

Lluch-Cota, S. E., E. A. Aragón-Noriega, F. Arreguín-Sánchez, D. Aurioles-Gamboa, J. J. Baustista-Romero, R. C. Brusca, R. Cervantes-Durarte, R. Cortés-Altamirano, P. Del-Monte-Luna, A. Esquivel-Herrera, G. Fernández, M. E. Hendrickx, S. Hernández-Vázquez, H. Herrerra-Cervantes, M. Kahru, M. F. Lavín, D. Lluch-Belda, D. B. Lluch-Cota, J. López-Martínez, S. G. Marinone, M. O. Nevárez-Martínez, S. Ortega-García, E. Palacios-Castro, A. Parés-Sierra, G. Ponce-Díaz, M. Ramírez-Rodríguez, C. A. Salinas-Zavala, R. A. Schwartzlose, and A. P. Sierra-Beltrán. 2007. The Gulf of California: review of ecosystem status and sustainability challenges. Progress in Oceanography 73:1–26.

Lozano-Montes, H. 2006. Historical ecosystem modelling of the upper Gulf of California (Mexico): following 50 years of change. Doctoral dissertation. University of British Columbia, Vancouver.

Lozano-Montes, H. M., T. J. Pitcher, and N. Haggan. 2008. Shifting environmental and cognitive baselines in the upper Gulf of California. Frontiers in Ecology and the Environment 6:75–80.

Magallon-Barajas, F. J. 1987. The Pacific shrimp fishery of Mexico. California Cooperative Oceanic Fisheries Investigations Reports 28:43–52.

Musick, J. A., M. M. Harbin, A. Berkeley, G. H. Burgess, A. M. Eklund, L. T. Findley, R. G. Gilmore, J. T. Golden, D. S. Ha, G. R. Huntsman, J. C. McGovern, S. J. Parker, S. G. Poss, E. Sala, T. W. Schmidt, G. R. Sedberry, H. Weeks, and S. G. Wright. 2000. Marine, estuarine and diadromous fish stocks at risk of extinction in North America (exclusive of Pacific salmonids). Fisheries 25(11):6–30.

Nevárez-Martínez, M. O., F. J. Méndez-Tenorio, C. Cervates-Valle, J. López-Martínez, and M. L. Anguiano-Carrasco. 2006. Growth, mortality, recruitment, and yield of the jumbo squid (*Dosidicus gigas*) off Guaymas, Mexico. Fisheries Research (Amsterdam) 79:38–47.

Palacios, E., and L. Alfaro. 2005. Seabird research and monitoring meeds in northwestern México. Pages 151–156 *in* C. J. Ralph and D. Terrell, editors. U.S. Forest Service Technical Report PSW-GTR-191.

Pauly, D. 1984. Fish population dynamics in tropical waters; a manual for use with programmable calculators. International Center for Living Aquatic Resource Management, Studies and Reviews, Manila.

Pauly, D. 1995. Anecdotes and the shifting baseline syndrome of fisheries. Trends in Ecology and Evolution 10:430.

Pikitch, E. K., C. Santora, E. A. Babcock, A. Bakun, R. Bonfil, D. O. Conover, P. Dayton, P. Doukakis, D. Fluharty, B. Heneman, E. D. Houde, J. Link, P. A. Livingston, M. Mangel, M. K. Allister, J. Pope, and K. J. Sainsbury. 2004. Ecosystem-based fishery management. Science (Washington, D.C.) 305:346–347.

Rodríguez, C., K. W. Flessa, and D. Dettman. 2001. Effects of upstream diversion of Colorado River water on the estuarine bivalve mollusk, *Mulina coloradensis*. Conservation Biology 15:249–258.

Rodríguez-Valencia, J. A., M. López-Camacho, D. Crespo, and M. A. Cisneros-Mata. 2008. Tamaño y distribución espacial de las flotas pesqueras ribereñas del Golfo de California en el año 2006, volumen I. Resultados y discusión. [Size and spatial distribution of coastal fishing fleets in the Gulf of California in 2006, volume I. Results and discussion.] Available: wwf.org.mx/wwfmex/descargas/rep_tamanio_distribucion_flotas_pesqueras_080710.pdf. (February 2010).

Sadovy, Y. 2001. The threat of fishing to highly fecund fishes. Journal of Fish Biology 59(Supplement A):90–108.

Downloaded From: https://bioone.org/journals/Marine-and-Coastal-Fisheries:-Dynamics,-Management,-and-Ecosystem-Science on 29 Mar 2024
Terms of Use: https://bioone.org/terms-of-use

Sáenz-Arroyo, A., C. M. Roberts, J. Torre, M. Cariño-Olvera, and R. Enríquez-Andrade. 2005. Rapidly shifting environmental baselines among fishers of the Gulf of California. Proceedings of the Royal Society 272B:1957–1962.

Schaefer, M. B. 1954. Some aspects of the dynamics of populations important to the management of commercial marine fisheries. Bulletin of the Inter-American Tropical Tuna Commission 1:25–56.

Silvestre, G., and D. Pauly. 1997. Management of tropical coastal fisheries in Asia: an overview of key challenges and opportunities. Pages 8–25 *in* G. Sivestre and D. Pauly, editors. ICLARM (International Center for Living Aquatic Resource Management) conference proceedings 53: status and management of tropical coastal fisheries in Asia. ICLARM, Studies and Reviews, Manila.

INEGI (Instituto Nacional de Estadística y Geografía) and Government of Sonora. 2008a. Anuario estadístico de Sonora: Puerto Peñasco. [Statistical annual for Sonora: Puerto Peñasco.] Available: 1economiasonora.gob.mx/files_estadistica/perfiles_english/Socieconomic%20Overview%20PUERTO%20PENASCO.pdf. (February 2010).

INEGI (Instituto Nacional de Estadística y Geografía) and Government of Sonora. 2008b. Anuario estadístico de Sonora: San Felipe de Jesus. [Statistical annual for Sonora: San Felipe de Jesús.] Available: 1economiasonora.gob.mx/files_estadistica/perfiles_english/Socieconomic%20Overview%20SAN%20FELIPE%20DE%20JESUS.pdf. (February 2010).

Stevens, J. D., R. Bonfil, N. K. Dulvy, and P. A. Walker. 2000. The effects of fishing on sharks, rays, and chimaeras (chondrichthyans), and the implications for marine ecosystems. ICES Journal of Marine Science 57:476–494.

Szteren, D., D. Aurioles, and L. R. Gerber. 2006. Population status and trends of the California sea lion (*Zalophus californianus californianus*) in the Gulf of California, Mexico. Pages 369–384 *in* A. W. Trites, S. K. Atkinson, D. P. DeMaster, L. W. Fritz, T. S. Gelatt, L. D. Rea, and K. M. Wynne, editors. Proceedings of the 22nd Lowell Wakefield fisheries symposium: sea lions of the world. University of Alaska, Alaska Sea Grant, Fairbanks.

Turvey, S. T., L. A. Barrett, H. Yujiang, Z. Lei, Z. Xinqiao, W. Xianyan, H. Yadong, Z. Kaiya, T. Hart, and W. Ding. 2009. Forgetting the Yangtze freshwater megafauna: rapid shifting baselines in Yangtze fishing communities, and local memory of extinct species. Conservation Biology 24:778–787.

Velarde, E., and D. W. Anderson. 1994. Conservation and management of seabirds islands in the Gulf of California: setbacks and successes. Pages 229–243 *in* D. N. Nettleship, J. Burger and M. Gochfeld, editors. Seabirds on islands: threats, case studies and action plans. Birdlife International, Cambridge, Massachusetts.

Wielgus, J., M. Gonzalez-Suarez, D. Aurioles-Gamboa, and L. R. Gerber. 2008. A noninvasive demographic assessment of sea lions based on stage-specific abundances. Ecological Applications 18:1287–1296.

Zadeh, L. A. 1965. Fuzzy sets. Information and Control 8:338–353.

Zadeh, L. A. 1999. Fuzzy logic = computing with words. Pages 3–23 *in* L. A. Zadeh and J. Kacprzyk, editors. Computing with words in information/intelligent systems, volume 1. Studies in fuzziness and soft computing. Springer-Verlag, New York.

Downloaded From: https://bioone.org/journals/Marine-and-Coastal-Fisheries:-Dynamics,-Management,-and-Ecosystem-Science on 29 Mar 2024
Terms of Use: https://bioone.org/terms-of-use

Appendix: Supplemental Material for Quantifying Species Abundance Trends

TABLE A.1. Availability of data by functional group. The composition of the groups is given in Table A.5.

	Abundance indicator			Exploitation indicator		
Functional group	Abundance	CPUE	Depletion	Harvest model exploitation	Vulnerability	Size reduction
Gulf coney	√	√	√			√
Extranjero	√	√	√			√
Gulf grouper	√	√	√			√
Amarillo snapper			√		√	√
Barred pargo	√	√	√			√
Groupers and snappers	√	√	√	√	√	√
Drums and croakers	√	√	√	√	√	√
Grunts		√		√	√	
Herbivorous fish		√	√		√	√
Large reef fish		√	√		√	√
Small reef fish		√	√		√	√
Small demersal fish		√		√	√	
Pacific angel shark	√	√	√		√	√
Small migratory sharks	√	√	√	√	√	√
Large pelagic sharks	√		√	√	√	√
Guitarfish	√	√	√	√	√	√
Skates, rays and sharks	√	√	√	√	√	√
Flatfish	√	√	√	√	√	√
Mojarra		√	√	√	√	√
Scorpionfish			√	√	√	√
Totoaba	√	√	√	√	√	√
Large pelagics		√	√		√	
Mackerel	√	√	√	√	√	√
Hake		√	√	√	√	√
Small pelagics		√	√	√	√	√
Mysticeti	√		√	√		√
Odontocetae	√		√	√		√
Vaquita			√	√		√
Pinnipeds	√		√	√		√
Reef-associated turtles	√	√	√			√
Scallops and penshells	√	√	√			√
Penaeid shrimp	√	√	√	√		√
Sea cucumbers		√	√			√
Crabs and lobsters	√	√	√	√		√
Herbivorous echinoderms			√			√
Carnivorous macrobenthos	√	√	√	√		√
Bivalves	√	√	√	√		√
Snails	√	√	√	√		√
Adult blue crab		√				
Macroalgae		√		√		
Adult blue shrimp		√		√		
Squid		√				

Downloaded From: https://bioone.org/journals/Marine-and-Coastal-Fisheries:-Dynamics,-Management,-and-Ecosystem-Science on 29 Mar 2024
Terms of Use: https://bioone.org/terms-of-use

TABLE A.2. Catch and effort references.

Catch

1. Aragón-Noriega, E. 2006. Las áreas naturales protegidas como instrumento de manejo pesquero y conservación de la biodiversidad: caso de la reserva de la biosfera del alto Golfo de California y delta del Río Colorado. [Protected natural areas as instruments for fisheries management and the conservation of biodiversity: a case study in the upper Gulf of California and Colorado River delta biosphere reserve]. Pages 73–88 *in* B. S. Faijo-Sing, S. B. Echeverria-Castro, and C. O. Tapia-Fonllem, editors. Desierto y mar: estudios sociales en Sonora. [Desert and sea: social studies in Sonora.] Instituto Tenológico de Sonora, Guaymas, Mexico.
2. Arvizu, J., and H. Chavez. 1970. Synopsis of the biology of the totoaba *Cynoscion macdonaldi* (Gilbert 1890). FAO (Food and Agriculture Organization of the United Nations) Fisheries Synopsis 108.
3. Berdegue, J. 1955. La pesquería de la totoaba (*Cynoscion macdonaldi* Gilbert) en San Felipe, Baja California. [The totoaba (*Cynoscion macdonaldi* Gilbert) fishery in San Felipe, Baja California]. Revista de la Sociedad Mexicana de Historia Natural 16(1–4):45–76.
4. Conapesca (Comisión Nacional de Acuacultura y Pesca). 2009. Anuario estadístico de acuacultura y pesca (1980–2000). [Statistical annual for aquaculture and fisheries (1980–2000).] Available: www.conapesca.sagarpa.gob.mx. (April 2009).
5. Diario Oficial de la Federación. 2004. Acuerdo mediante el cual se aprueba la actualización de la Carta Nacional Pesquera, segunda sección. [Agreement approving the update of the National Fisheries Catalog, second section.] Secretaría de Agricultura, Ganadería, Desarrollo Rural, Pesca, y Alimentación, Mexico City. Available: http://www.inapesca.bog.mx/portal/documentos/publicaciones/pelagicos.
6. Diario Oficial de la Federación. 2006. Acuerdo mediante el cual se aprueba la actualización de la Carta Nacional Pesquera, primera sección [Agreement approving the update of the National Fisheries Catalog, first section.] Secretaría de Agricultura, Ganadería, Desarrollo Rural, Pesca, y Alimentación, Mexico City. Available: http://www.inapesca.bog.mx/portal/documentos/publicaciones/pelagicos.
7. Espino-Barr, E., D. Hernández-Montaño, E. Cabrera-Mancilla, R. M. Gutiérrez-Zavala, H. A. Gil-López, E. G. Cabral-Solís, A. Garcia-Boa, C. Meléndez, M. Puente-Gómez, and R. Acosta. 2006. Huachinango del Pacífico sur. [Red snapper of the southern Pacific.] Pages 103–129 *in* F. Arreguín-Sánchez, L. Beléndez-Moreno, I. M. Gómez-Humarán, R. Solana Sansores, and C. Rangel-Dávalos, editors. Sustentabilidad y pesca responsable en México. [Sustainability and responsible fishing in Mexico.] Instituto Nacional del la Pesca, Mexico City.
8. Galindo-Bect, M. S. 2003. Larvas y postlarvas de camarones peneidos en el alto Golfo de California y capturas de camarón con relación al flujo del Río Colorado. [Larvae and postlarvae of penaeid shrimp in the upper Gulf of California and shrimp catch in relation to the flow of the Colorado River.] Doctoral dissertation. Universidad Autónoma de Baja California, Ensenada.
9. López-Martínez, J., F. Arreguín-Sánchez, R. Morales-Azpeitia, and C. Salinas-Zavala. 2002. Stock assessment and potential yield for the rock shrimp, *Sicyonia penicillata*, fishery of Bahía Kino, Sonora, Mexico. Fisheries Research 59(1–2):71–81.
10. Magallón-Barajas, F. J. 1987. The Pacific shrimp fishery of Mexico. California Cooperative Oceanic Fisheries Investigations 28:43–52.
11. Ramírez, E. G. 1967. Resumen estadístico de la captura anual de totoaba en el Golfo de California en el periodo 1929–1966. [Statistical summary of the annual catch of totoaba in the Gulf of California over the period 1929–1966.] Trabajos de Divulgación 13(124):1–31.
12. Rodríguez-Quiroz, G., and E. A. Aragón-Noriega. Centro Interdisciplinario de Investigación para el Desarrollo Integral Regional, Sinaloa unit, unpublished manuscript.
13. Rodríguez-Quiroz, G., E. A. Aragón-Noriega, M. A. Cisneros-Mata, L. F. Beltrán-Morales, and A. Ortega-Rubio. Centro Interdisciplinario de Investigación para el Desarrollo Integral Regional, Sinaloa unit, unpublished manuscript.
14. Rojas-Bracho, L., R. R. Reeves, and A. Jaramillo-Legorreta. 2006. Conservation of the vaquita *Phocoena sinus*. Mammal Review 36:179–216.

Effort

15. Nevárez-Martínez, M. O., M. Martínez-Zavala, C. E. Cotero-Altamirano, M. L. Jacob-Cervantes, Y. Gren-Ruiz, G. Gluyas-Millán, A. Cota-Villavicencio, and J. P. Santos-Molina. 2006. Peces pelágicos menores. [Small pelagic fishes.] Pages 265–301 *in* F. Arreguín-Sánchez, L. Beléndez-Moreno, I. M. Gómez-Humarán, R. Solana Sansores, and C. Rangel-Dávalos, editors. Sustentabilidad y pesca responsable en México. [Sustainability and responsible fishing in Mexico.] Instituto Nacional del la Pesca, Mexico City.
16. Galindo-Bect, M. S., 2003. Larvas y postlarvas de camarones peneidos en el Alto Golfo de California y capturas de camarón con relacion al flujo del Río Colorado. [Larvae and postlarvae of penaeid shrimp in the Upper Gulf of California and shrimp catch in relation to the flow of the Colorado River.] Doctoral dissertation. Universidad Autónoma de Baja California, Ensenada.

Downloaded From: https://bioone.org/journals/Marine-and-Coastal-Fisheries:-Dynamics,-Management,-and-Ecosystem-Science on 29 Mar 2024
Terms of Use: https://bioone.org/terms-of-use

TABLE A.2. Continued.

17. Galindo-Bect, M. S., E. P. Glenn, H. M. Page, K. Fitzsimmons, L. A. Galindo-Bect, J. M. Hernandez-Ayon, R. L. Petty, J. Garcia-Hernandez, and D. Moore. 2000. Penaeid shrimp landings in the upper Gulf of California in relation to Colorado River freshwater discharge. U.S. National Marine Fisheries Service Fishery Bulletin 98:222–225.
18. Lercari, D., and E. A. Chavez. 2007. Possible causes related to historic stock depletion of the totoaba, *Totoaba macdonaldi* (Perciformes: Sciaenidae), endemic to the Gulf of California. Fisheries Research 86:136–142.
19. Magallón-Barajas, F. J. 1987. The Pacific shrimp fishery of Mexico. California Cooperative Oceanic Fisheries Investigations 28:43–52.
20. Palleiro-Nayar, J., D. Aguilar-Montero, and L. Salgado-Rogel. 2006. La pesquería de erizo de mar. [The sea urchin fishery.] Pages 89–100 *in* F. Arreguín-Sánchez., L. Beléndez-Moreno, I., M. Gómez-Humarán, R. Solana Sansores, and C. Rangel-Dávalos, Editors. Sustentabilidad y pesca responsable en México. [Sustainability and responsible fishing in Mexico.] Instituto Nacional del la Pesca, Mexico City.
21. Rodríguez-Quiroz, G. 2008. Sociedad pesca y conservación en la reserva de la biosfera del alto Golfo de California y delta del Río Colorado. [Fisheries and conservation in the Upper Gulf of California Biosphere Reserve and Colorado River Delta]. Doctoral dissertation. Centro de Investigaciones Biológicas del Noroeste, La Paz.
22. Vega-Velásquez, A. 2006. Langosta de la península de Baja California. [Lobsters of the Baja California peninsula]. Pages 157–210 *in* P. Cuellar and C. O. Cadena, editors. Sustentabilidad y pesca responsable en México. Insituto Nacional de la Pesca, Mexico City.

TABLE A.3. Life history parameter references. Numbers preceded by the letters FB are Fishbase reference numbers searchable at www.fishbase.org; all other numbers refer to the references in Table A.4. The composition of the groups is given in Table A.5.

Functional group	References
Gulf coney	1,29,45,50,80
Extranjero	1,8,29,52,FB9342
Leopard grouper	1,29,32,35,52,84,92
Gulf grouper	1,85,FB6323
Amarillo snapper	25,28,81,82,96,FB6323,FB30872
Barred pargo	3,29,FB6323
Groupers and snappers	7,14,29,46,50,52,FB55,FB2850,FB3083,FB3090,FB3094,FB3244,FB4841,FB5227,FB5592, FB6323,FB6852,FB7185,FB9342,FB26176,FB27020,FB39376,FB40592,FB46367,FB47696
Drums and croakers	6,18,19,29,39,52,59,60,64,71,73,79,88,98,FB1164,FB1166,FB1180,FB6323,FB6997,FB26176
Grunts	2,36,39,46,60,62,67,FB2850,FB9114,FB11035,FB26176,FB26585,FB40926
Herbivorous fish	43,46,51,59,62,71,93,94,95,FB268,FB273,FB1048,FB1049,FB1238,FB1396,FB1836,FB2334, FB2850,FB3678,FB3807,FB4617,FB5533,FB5592,FB5760,FB6380,FB6997,FB7253,FB8540, FB8571,FB9072,FB9267,FB9310,FB9338,FB11824,FB12360,FB12544,FB13715,FB26177, FB26587,FB28725,FB29555,FB30504,FB42001,FB48600
Large reef fish	10,14,16,19,26,37,38,52,59,60,71,101,FB1263,FB1602,FB1751,FB2850,FB3669,FB3678, FB3807,FB4525,FB4604,FB5227,FB5525,FB5592,FB6323,FB6390,FB6490,FB7142,FB8571, FB9276,FB9292,FB9311,FB9312,FB9328,FB9329,FB9341,FB11482,FB11824,FB12260,FB26112, FB26585,FB26587,FB27803,FB28688,FB37992,FB39266,FB39376,FB40789,FB40870,FB48600
Small reef fish	23,24,31,33,38,39,46,52,55,57,58,59,60,68,75,86,FB273,FB559,FB583,FB1602,FB1661,FB2272, FB2850,FB3141,FB3678,FB3807,FB5227,FB5525,FB5590,FB5592,FB6113,FB6323,FB6937, FB7247,FB9072,FB9269,FB9286,FB9289,FB9299,FB9307,FB9324,FB9333,FB9334,FB9348, FB9349,FB9710,FB11482,FB11824,FB26176,FB26177,FB26585,FB26587,FB28023,FB30504, FB30573,FB37955,FB50710

Downloaded From: https://bioone.org/journals/Marine-and-Coastal-Fisheries:-Dynamics,-Management,-and-Ecosystem-Science on 29 Mar 2024
Terms of Use: https://bioone.org/terms-of-use

TABLE A.3. Continued.

Functional group	References
Small demersal fish	2,14,27,52,54,59,60,72,75,100,FB273,FB1371,FB2272,FB2850,FB3669,FB3678,FB4423, FB4461,FB4525,FB4925,FB5778,FB6323,FB6347,FB8571,FB8991,FB9269,FB9271,FB9277, FB9279,FB9284,FB9301,FB9307,FB9324,FB9348,FB9992,FB10887,FB11482,FB11824,FB26176, FB26585,FB26587,FB26773,FB27327,FB28023,FB31276,FB32350,FB34120,FB34613,FB35910, FB37955,FB38374,FB38398,FB39877,FB43481
Pacific angel shark	13,43,60,FB6147
Small migratory sharks	14,102,FB244,FB6097,FB6098,FB9253
Large pelagic sharks	14,43,60,66,FB244,FB273,FB1661,FB1671,FB3213,FB3222,FB3678,FB6084,FB6088,FB6090, FB6390,FB6937,FB7200,FB8571,FB9012,FB9165,FB11824,FB12489,FB13713,FB26587, FB27093,FB27603,FB27605,FB27971,FB31395,FB31509,FB32047,FB32086,FB32407,FB35388, FB36559,FB41862,FB42004
Guitarfish	14,83,FB2850,FB6323,FB9262
Skates, rays, and sharks	14,15,52,63,71,78,89,FB244,FB247,FB2850,FB3678,FB5255,FB6145,FB6323,FB6871,FB9255, FB9257,FB9259,FB9261,FB9265,FB28023,FB43028
Flatfish	14,34,41,52,56,59,60,76,77,FB2272,FB2850,FB6997,FB9047,FB9281,FB9294,FB9330,FB9331, FB11035,FB36656,FB41284,FB42865,FB43299,FB47359,FB47696
Mojarra	14,46,FB6937,FB6997,FB8540,FB8571,FB9303,FB11824,FB26176
Scorpionfish	59,60,61,71,FB2850,FB5592,FB5760,FB6937,FB7055,FB9341,FB9352,FB11824,FB26176, FB27129,FB41274
Lanternfish and deep	69,FB2850,FB4525,FB28499,FB40826
Totoaba	5,19,20,40,71,FB796
Large pelagics	4,11,12,14,39,43,44,49,52,59,60,70,71,74,91,99,FB14,FB26,FB168,FB238,FB268,FB273,FB515, FB1139,FB1263,FB1314,FB1333,FB1345,FB1374,FB1386,FB1392,FB1414,FB1447,FB1449, FB1462,FB1467,FB1475,FB1498,FB1656,FB2850,FB2885,FB3555,FB3605,FB3669,FB3678, FB3786,FB4332,FB4525,FB4560,FB4838,FB4972,FB5337,FB5338,FB5340,FB5525,FB5730, FB5760,FB5964,FB6323,FB6390,FB6814,FB6937,FB7161,FB7173,FB7253,FB8571,FB9283, FB9319,FB9345,FB9346,FB9898,FB9987,FB11482,FB11824,FB12193,FB12260,FB12451, FB12757,FB13304,FB26319,FB26340,FB26370,FB26587,FB26849,FB27030,FB28023,FB28050, FB28958,FB32349,FB33193,FB34133,FB34137,FB34148,FB35465,FB36276,FB36645,FB36658, FB36794,FB37040,FB37813,FB41559,FB41779,FB43794,FB46593
Mackerel	14,43,43,49,52,53,62,65,71,97,FB766,FB796,FB1662,FB3578,FB3730,FB3733,FB4332, FB4525,FB4530,FB5760,FB5960,FB5964,FB6014,FB6323,FB7032,FB7193,FB12393, FB13305,FB28200,FB33255,FB35185,FB39376,FB40755,FB42455
Hake	9,17,71,FB1139
Small pelagics	14,21,22,30,42,46,47,48,49,59,60,71,87,90,FB188,FB189,FB796,FB831,FB833,FB835, FB839,FB840,FB850,FB905,FB907,FB908,FB909,FB917,FB1139,FB1836,FB2197,FB2850, FB3231,FB3669,FB3678,FB3730,FB4525,FB5760,FB5769,FB5888,FB6997,FB9273,FB9291, FB9298,FB9300,FB9336,FB10851,FB11192,FB11482,FB26420,FB27758,FB33192,FB33520, FB34034,FB37813,FB39882,FB41293

Downloaded From: https://bioone.org/journals/Marine-and-Coastal-Fisheries:-Dynamics,-Management,-and-Ecosystem-Science on 29 Mar 2024
Terms of Use: https://bioone.org/terms-of-use

TABLE A.4. Full references for life history parameters.

1. Aburto-Oropeza, O., E. Ezcurra, G. Danemann, V. Valdez, J. Murray, and E. Sala. 2008. Mangroves in the Gulf of California increase fishery yields. Proceedings of the National Academy of Sciences of the USA 105:10456–10459.
2. Aguirre, H., F. Amezcua, J. Madrid-Vera, and C. Soto. 2008. Length–weight relationship for 21 fish species from a coastal lagoon in the southwestern Gulf of California. Journal of Applied Ichthyology 24:91–92.
3. Allen, L. G. 1985. A habitat analysis of the nearshore marine fishes from southern California. Bulletin of the Southern California Academy of Sciences 84(3):133–155.
4. Ally, J. R. R., and K. Miller. 1992. California barracuda. Pages 157–160 *in* W. S. Leet, C. M. Dewees, and C. W. Haugen, editors. California's living marine resources and their utilization. University of California–Davis, California Sea Grant Extension Program, Davis.
5. Almeida-Paz, M., G. Morales-Abril, and M. J. Roman-Rodriguez. 1992. Aspectos sobre aclimatación y crecimiento de juveniles de totoaba, *Totoaba macdonaldi* (Gilbert) (Pisces: Sciaenidae) en condicions de cautiverio. [Aspects of acclimatization and growth of juvenile totoaba, *Totoaba macdonaldi* (Gilbert) (Pisces: Sciaenidae) in captivity.] Ecologica 2:7–12.
6. Alvarez Tinarejo, M. D. C. 1997. Análisis microscópico gonadal y fecundidad del chano *Micropogonias megalops* en el litoral del alto Golfo de California para el período 1993–1995. [Microscopic gonadal analysis and fecundity of chano *Micropogonias megalops* in the nearshore areas of the upper Gulf of California for the period 1993–1995.] Master's thesis. Universidad Autónoma de Baja California, Ensenada, Mexico.
7. Arreguín-Sánchez, F., L. Beléndez-Moreno, I. M. Gómez-Humarán, R. Solana Sansores, and C. Rangel Dávalos, editors. 2006. Sustentabilidad y pesca responsable en México. [Sustainability and responsible fishing in Mexico.] Instituto Nacional de la Pesca, Mexico City.
8. Avilés Quevedo, A. 1995. Biología y cultivo de la cabrilla arenera *Paralabrax maculatofasciatus* (Steindachner, 1868). [Biology and cultivation of spotted sand bass *Paralabrax maculatofasciatus*.] Centro Regional de Investigación Pesquera, La Paz, Mexico.
9. Balart-Páez, E. F. 2005. Biología y ecología de la *Merluza bajacalifornian*a, *Merluccius angustimanus* Garman, 1899, en la costa occidental de Baja California Sur, México. [Biology and ecology of *Merluza bajacalifornian*a, *Merluccius angutimanus* Garman 1899 in coastal waters of Baja California Sur.] Doctoral dissertation. Universidad Autónoma de Nuevo León, Monterrey, Mexico.
10. Barroso-Soto, I., E. Castillo-Gallardo, C. Quiñonez-Velazquez, and R. E. Morán-Angulo. 2007. Age and growth of the finescale triggerfish *Balistes polylepis* (Teleostei: Balistidae) on the coast of Mazatlán, Sinaloa, Mexico. Pacific Science 61(1):121–127.
11. Baxter, J. L. 1960. The sport and commercial fisheries. California Department of Fish and Game, Fish Bulletin 110:14–22.
12. Baxter, J. L., and R. D. Collyer. 1960. Results of tagging experiments. California Department of Fish and Game, Fish Bulletin 110:52–77.
13. Bedford, D. W. 1987. Pacific angel shark. California Department of Fish and Game, Management Information Document, Long Beach.
14. Brand, E. J., I. C. Kaplan, C. J. Harvey, P. S. Levin, E. A. Fulton, A. J. Hermann, and J. C. Field. 2007. A spatially explicit ecosystem model of the California Current's food web and oceanography. NOAA Technical Memorandum NMFS-NWFSC-84.
15. Cailliet, G. M., E. J. Burton, J. M. Cope, L. A. Kerr, R. J. Larson, R. N. Lea, D. VenTresca, and E. Knaggs. 2000. Biological characteristics of nearshore fishes of California: a review of existing knowledge and proposed additional studies for the Pacific Ocean. Pacific States Marine Fisheries Commission, Final Report, Portland, Oregon.
16. CDFG (California Department of Fish and Game). 1982. California fish and wildlife plan, volume II. Species plans, part C. Living marine resources, preliminary draft. CDFG, Sacramento.
17. Casas-Valdez, M., and G. Ponce-Díaz, editors. 1996. Estudio del potencial pesquero y acuícola de Baja California Sur, volume 1. [Study of the fishing and aquaculture potential of Baja California Sur.] Government of Baja California Sur, La Paz, Mexico.
18. Castro Gonzalez, J. J. 2004. Estudio base y estrategias de manejo de la pesquería del chano *Micropogonias megalops*: caso de studio—Alto Golfo de California. [Basic study and management strategies for the chano *Micropogonias megalops* fishery: case study—upper Gulf of California.] Master's thesis. Universidad Autónoma de Baja California, Ensenada, Mexico.

Downloaded From: https://bioone.org/journals/Marine-and-Coastal-Fisheries:-Dynamics,-Management,-and-Ecosystem-Science on 29 Mar 2024
Terms of Use: https://bioone.org/terms-of-use

TABLE A.4. Continued.

19. Chao, L. N. 1995. Sciaenidae: Corvinas, barbiches, bombaches, corvinatas, corvinetas, corvinillas, lambes, pescadillas, roncachos, verrugatos. Pages 1427–1518 *in* W. Fischer, F. Krupp, W. Schneider, C. Sommer, K. E. Carpenter, and V. Niem, editors. Guía FAO para identificación de especies para los fines de la pesca: Pacífico centro-oriental. [FAO species identification guide for fishery purposes: east-central Pacific.] Food and Agriculture Organization of the United Nations, Rome.
20. Cisneros-Mata, M. A., G. Montemayor-López, and M. J. Román-Rodríguez. 1995. Life history and conservation of *Totoaba macdonaldi*. Conservation Biology 9:806–814.
21. Clark, F. N. 1925. The life history of *Leuresthes tenuis*, an atherine fish with tide-controlled spawning habits. California Department of Fish and Game, Fish Bulletin 10:1–51.
22. Clark, F. N. 1929. The life history of the California jack smelt, *Atherinopsis californiensis*. California Department of Fish and Game, Fish Bulletin 16:5–22.
23. Clarke, T. A. 1970. Territorial behavior and population dynamics of a pomacentrid fish, the garibaldi, *Hypsypops rubicunda*. Ecological Monographs 40(2):189–212.
24. Clarke, T. A. 1971. Territoriality boundaries, courtship, and social behavior in the garibaldi, *Hypsypops rubicunda* (Pomacentridae). Copeia 1971:295–299.
25. Cotto Sanchéz, A., 1998. Listado taxonómico de los peces identificados en los océanos Pacífico y Atlántico de Nicaragua. [Taxonomic list of fish identified in the Pacific and Atlantic oceans off Nicaragua.] Ministerio de Economía y Desarrollo. Managua, Nicaragua.
26. Cowen, R. K. 1990. Sex changes and life history patterns of the labrid, *Semicossyphus pulcher*, across an environmental gradient. Copeia 1990:787–795.
27. Crane, J. M. 1981. Feeding and growth by the sessile larvae of the teleost *Porichthys notatus*. Copeia 1981:895–897.
28. Cruz-Romero, M., E. Espino-Barr, J. Mimbela-Lopez, A. Garcia-Boa, L. F. Obregon-Alcaraz, and E. Giron-Botello. 1991. Biología reproductiva en tres especies del genero *Lutjanus* en la costa de Colima, México. [Reproductive biology of three species in the genus *Lutjanus* on the coast of Colima, Mexico.] Centro Regional de Investigación Pesquera–Manzanillo, Manzanillo, Colima, Mexico.
29. R. Cudney-Bueno and coworkers, University of Arizona, unpublished data.
30. DeLeon, S. 1999. Atherinidae. Pages 217–248 in J. Orsi, editor. Report on the 1980–1995 fish, shrimp, and crab sampling in the San Francisco estuary, California. California Department of Fish and Game, Technical Report 63.
31. DeMartini, E. E., A. M. Barnett, T. D. Johnson, and R. F. Ambrose. 1994. Growth and production estimates for biomass-dominant fishes on a southern California artificial reef. Bulletin of Marine Science 55(2–3):484–500.
32. Díaz-Uribe, F. G., J. F. Elorduy-Garay, and M. T. González-Valdovinos. 2001. Age and growth of the leopard grouper, *Mycteroperca rosacea*, in the southern Gulf of California, Mexico. Pacific Science 55(2):171–182.
33. Díaz-Uribe, J., and S. S. Ruíz-Cordova. 1989. Edad y crecimiento del "conejo," *Caulolatilus affinis* Gill 1865 (Pisces: Branchiostegidae) en la Bahía de La Paz y sus alrededores, Baja California Sur, México. [Age and growth of the "conejo," *Caulolatilus affinis* Gill 1865 (Pisces: Branchiostegidae) in La Paz Bay and its environs, Baja California Sur, Mexico.] Doctoral dissertation. Universidad Autónoma de Baja California Sur, La Paz, Mexico.
34. Emmett, R. L., S. A. Hinton, S. L. Stone, and M. E. Monaco. 1991. Distribution and abundance of fishes and invertebrates in West Coast estuaries, volume II. Species life history summaries. National Oceanic and Atmospheric Administration, Estuarine Living Marine Resources Report 8, Rockville, Maryland.
35. Erisman, B. E., M. L. Buckhorn, and P. A. Hastings. 2007. Spawning patterns in the leopard grouper, *Mycteroperca rosacea*, in comparison with other aggregating groupers. Marine Biology 151:1849–1861.
36. Feder, H. M., C. H. Turner, and C. Limbaugh. 1974. Observations on fishes associated with kelp beds in southern California. California Department of Fish and Game, Fish Bulletin 160.
37. Field, J. 2004. Application of ecosystem-based fishery management approaches in the northern California Current. Doctoral dissertation. University of Washington, Seattle.
38. Fitch, J. E. 1960. Black sea bass. Pages 48–49 *in* California ocean fisheries resources to the year 1960. California Department of Fish and Game, Sacramento.
39. Fitch, J. E., and R. J. Lavenberg. 1971. Marine food and game fishes of California. University of California Press, Berkeley.
40. Fitch, J. E., and R. J. Lavenberg. 1975. Tidepool and nearshore fishes of California. University of California Press, Berkeley.
41. Flanagan, C. A., and J. R. Hendrickson. 1976. Observations on the commercial fishery and reproductive biology of the totoaba, *Cynoscion macdonaldi*, in the northern Gulf of California. U.S. National Marine Fisheries Service Fishery Bulletin 74:531–544.
42. Ford, R. F. 1965. Distribution, population dynamics, and behavior of a bothid flatfish, *Citharichthys stigmaeus*. Doctoral dissertation. University of California–San Diego, San Diego.

Downloaded From: https://bioone.org/journals/Marine-and-Coastal-Fisheries:-Dynamics,-Management,-and-Ecosystem-Science on 29 Mar 2024
Terms of Use: https://bioone.org/terms-of-use

TABLE A.4. Continued.

43. Fritzsche, R. A., R. H. Chamberlain, and R. A. Fisher. 1985. Species profile: life histories and environmental requirements of coastal fishes and invertebrates (Pacific southwest): California grunion. U.S. Fish and Wildlife Service Biological Report 82(11.28) and U.S. Army Corp of Engineers report TR EL-82-4.
44. Froese, R., and D. Pauly, editors. 2008. Fishbase. Available: www.fishbase.org.
45. Gillanders, B. M., D. J. Ferrell, and N. L. Andrew. 1999. Aging methods for yellowtail kingfish, *Seriola lalandi*, and results from age- and size-based growth models. U.S. National Marine Fisheries Service Fishery Bulletin 97:812–827.
46. Gómez C., G. O., L. A. Zapata P., R. Franke. A., and G. E. Ramos T. 1999. Hábitos alimentarios de *Epinephelus acanthistius* y notas de otros peces serránidos capturados en el Parque Nacional Natural Gorgona, Pacífico colombiano. [Feeding grounds of *Epinephelus acanthistius* and notes on other serranid fishes in the Natural Gorgona National Park, Colombian Pacific.] Boletín de Investigación Marina y Costera 28:43–60.
47. González-Acosta, F., G. De La Cruz Agüero, and J. De La Cruz Agüero. 2004. Length–weight relationships of fish species caught in a mangrove swamp in the Gulf of California (Mexico). Journal of Applied Ichthyology 20:154–155.
48. Gregory, P. A. 1992. Silversides. Pages 78–81 *in* W. S. Leet, C. M. Dewees, and C. W. Haugen, editors. California's living marine resources and their utilization. University of California–Davis, California Sea Grant Extension Program, Publication UCSGEP-92–12, Davis.
49. Gunderson, D. 1997. Application of ecosystem-based fishery management approaches in the northern California Current. Doctoral dissertation. University of Washington, Seattle. [Cited by Field, J. 2004.]
50. Hart, J. L. 1973. Pacific fishes of Canada. Fisheries Research Board of Canada Bulletin 180.
51. Heemstra, P. C., and J. E. Randall. 1993. Groupers of the world (family Serranidae, subfamily Epinephelinae): an annotated and illustrated catalogue of the grouper, rockcod, hind, coral grouper and lyretail species known to date. FAO (Food and Agriculture Organization of the United Nations) Fisheries Synopsis 125:382.
52. Ibáñez-Aguirre, A. L., and M. Gallardo-Cabello. 1996. Age determination of the grey mullet *Mugil cephalus* L. and the white mullet *Mugil curema* V. (Pisces: Mugilidae) in Tamiahua Lagoon, Veracruz. Ciencias Marinas 22:329–345.
53. IGFA (International Game Fish Association). 2001. Database of IGFA angling records until 2001. IGFA, Fort Lauderdale, Florida. Available: www.igfa.org.
54. INP (Instituto Nacional de la Pesca). 2000. Sustentabilidad y pesca responsable en México: evaluación y manejo—la pesquería de sierra del Pacífico. [Sustainable and responsible fishing in Mexico: evaluation and management—the Pacific sierra fishery.] INP, Mexico City.
55. Jagielo, T., F. R. Wallace, and Y. W. Cheng. 2003. Assessment of lingcod (*Ophiodon elongatus*) for the Pacific Fishery Management Council in 2003. Washington Department of Fish and Wildlife, Mentesano. Available: www.pcouncil.org.
56. Kato, S. 1991. Ocean whitefish. Pages 92–112 *in* W. S. Leet, C. M. Dewees, and C. W. Haugen, editors. California's living marine resources and their utilization. University of California–Davis, California Sea Grant Extension Program, Publication UCSGEP-92-12, Davis.
57. Kramer, S. H., and J. S. Sunada. 1992. Flatfishes: California halibut. Pages 94–97 *in* W. S. Leet, C. M. Dewees, and C. W. Haugen, editors. California's living marine resources and their utilization. University of California–Davis, California Sea Grant Extension Program, Publication UCSGEP-92–12, Davis.
58. Limbaugh, C. 1955. Fish life in the kelp beds and the effects of kelp harvesting. Institute of Marine Resources, Reference 55-9, La Jolla, California.
59. Limbaugh, C. 1964. Notes on the life history of two Californian pomacentrids: garibaldis, *Hypsypops rubicunda* (Girard), and blacksmiths, *Chromis punctipinnis* (Cooper). Pacific Science 18:41–50.
60. Love, M. S. 1992. California scorpionfish. Pages 133–135 *in* W. S. Leet, C. M. Dewees, and C. W. Haugen, editors. California's living marine resources and their utilization. University of California–Davis, California Sea Grant Extension Program, Publication UCSGEP-92-12, Davis.
61. Love, M. S. 1996. Probably more than you want to know about the fishes of the Pacific Coast. Really Big Press, Santa Barbara, California.
62. Love, M. S., B. Axell, P. Morris, R. Collins, and A. Brooks. 1987. Life history and fishery of the California scorpionfish, *Scorpaena guttata*, within the southern California bight. U.S. National Marine Fisheries Service Fishery Bulletin 85:99–115.
63. Love, M. S., L. Thorsteinson, C. W. Mecklenburg, and T. A. Mecklenburg. 2000. A checklist of marine and estuarine fishes of the Northeast Pacific, from Alaska to Baja California. National Biological Service, Santa Barbara, California.

Downloaded From: https://bioone.org/journals/Marine-and-Coastal-Fisheries:-Dynamics,-Management,-and-Ecosystem-Science on 29 Mar 2024
Terms of Use: https://bioone.org/terms-of-use

TABLE A.4. Continued.

64. Mariano-Melendez, E. 1997. Biología reproductiva de la raya lodera *Dasyatis brevis* (Garman, 1880), en Bahía Almejas, B.C.S., México. [Reproductive biology of the *ray Dasyatis brevis* (Garman, 1880), in Almejas Bay, B.C.S., Mexico.] Master's thesis. Universidad Autónoma de Baja California Sur, La Paz, Mexico.
65. Maxwell, W. D. 1975. The croakers of California. State of California Marine Resources Leaflet 8.
66. Medina-Gómez, S. P. 2006. Edad y crecimiento de la sierra del Pacífico *Scomberomorus sierra* (Jordan y Starks, 1895), en el Golfo de California, México. [Age and growth of Pacific sierra *Scomberomorus sierra* (Jordan and Starks, 1895), in the Gulf of California, Mexico.] Master's thesis. Centro Interdisciplinario de Ciencias Marinas–Instituto Politéenico Nacional, La Paz, Mexico.
67. Mejia-Salazar, L. A. 2007. Biología reproductiva del cazón bironche, *Rhizoprionodon longurio* (Jordan y Gilbert, 1882), en el Pacífico méxicano. [Reproductive biology of the Pacific sharpnose shark, *Rhizoprionodon longurio* (Jordan and Gilbert, 1882). in the Mexican Pacific.] Master's thesis. Centro Interdisciplinario de Ciencias Marinas–Instituto Politéenico Nacional, La Paz, Mexico.
68. Miller, D. J., and R. N. Lea. 1972. Guide to the coastal marine fishes of California. California Department of Fish and Game, Fish Bulletin 157.
69. Neal, T. J. 1993. A test of the function of juvenile color patterns in the pomacentrid fish *Hypsypops rubicundus* (Teleostei: Pomacentridae). Pacific Science 47(3):240–247.
70. A. Orlov. 2008. Russian Federal Research Institute of Fisheries and Oceanography (VNIRO), unpublished data. [Cited by Froese and Pauly 2008.]
71. Pakoa, K. 1998. Vital statistics of marine fishes of Vanuatu. NAGA, the ICLARM Quarterly 21:27–29. [Cited by Froese and Pauly 2008.]
72. Pauly, D. 1978. A preliminary compilation of fish length growth parameters. Berichte aus dem Institut fuer Meereskunde an der Christian-Albrechts-Universitaet Kiel 55:1–200.
73. Phillips, A. C. 1973. Age determination and growth rate studies of the northern midshipman (*Porichthys notatus* Girard). Honor's thesis. University of Victoria, Victoria, British Columbia.
74. Pinkas, L. 1960. White seabass. Pages 49–51 *in* California ocean fisheries resources to the year 1960. Department of Fish and Game, Sacramento.
75. Pinkas, L. 1966. A management study of the California barracuda *Sphyraena argentea* Girard. California Department of Fish and Game, Fish Bulletin 134.
76. Quast, J. C. 1968. Fish fauna of the rocky inshore zone. California Department of Fish and Game, Fish Bulletin 139:35–55.
77. Rackowski, J. P., and E. K. Pikitch. 1989. Species profiles: life histories and environmental requirements of coastal fishes and invertebrates (Pacific Southwest)—Pacific and speckled sanddabs. U.S. Fish and Wildlife Service Biological Report 82(11.107). Available: www.nwrc.usgs.gov/wdb/pub/species_profiles/82_11-107.pdf
78. Reed, A. J., and A. D. Maccall. 1988. Changing the size limit: how could it affect California halibut fisheries. California Cooperative Oceanic Fisheries Investigations Reports 24:158-166.
79. Rodriguez-Lorenzo, S. 2007. Edad y crecimiento de la raya *Mariposa gymnura marmorata* (Cooper, 1863) del alto Golfo de California, México. [Age and growth of the ray *Mariposa gymnura marmorata* (Cooper, 1863) of the upper Gulf of California.] Master's thesis. Universidad Autónoma de Baja California, Ensenada, Mexico.
80. Rodríguez-Quiroz, G., and E. A. Aragón-Noriega. 2007. Artisanal fishing of bigeye croaker *Micropogonias megalops* (Gilbert, 1890) within the biosphere reserve of the upper Gulf of California and vaquita refuge area. Page 25 *in* Centro Interdisciplinario de Investigación para el Desarrollo Integral Regional, Santa Cruz Xoxocotlan, Mexico.
81. Rojas, P. A., and L. A. Zapata. 2006. Demersal fish of the National Natural Park Gorgona and its area of influence: Columbian Pacific. Biota Colombiana 7(2):213–244.
82. Rojas, P. A., C. Gutiérrez F., V. Puentes, A. A. Villa, and E. A. Rubio. 2004. Aspectos de la biología y dinámica poblacional del pargo coliamarillo *Lutjanus argentiventris* en el Parque Nacional Natural Gorgona, Colombia. [Aspects of the biology and population dynamics of the amarillo snapper *Lutjanus argentiventris* in Gorgona National Natural Park, Columbia.] Investigaciones Marinas 32:23–36.
83. Rojas-Bracho, L., R. R. Reeves, A. Jaramillo-Legorreta, and B. L. Taylor. 2007. *Phocoena sinus*. *In* IUCN red list of threatened species. IUCN (International Union for the Conservation of Nature) http://www.iucnredlist.org/apps/redlist/details/17028/o. (April 2009.)
84. Romo Curiel, A. E. 2004. Biología reproductiva del pez guitarra *Rhinobatos productus* Ayres, 1856 (Chondrichthyes : Rhinobatidae) en la región norte del Golfo de California, México. [Reproductive biology of the shovelnose guitarfish *Rhinobatos productus* Ayres, 1856 (Chondrichthyes : Rhinobatidae) in the northern Gulf of California, Mexico.] Master's thesis. Universidad Autónoma de Baja California, Ensenada, Mexico.

Downloaded From: https://bioone.org/journals/Marine-and-Coastal-Fisheries:-Dynamics,-Management,-and-Ecosystem-Science on 29 Mar 2024
Terms of Use: https://bioone.org/terms-of-use

TABLE A.4. Continued.

85. Saénz-Arroyo, A., C. M. Roberts, J. Torres, M. Cariño-Olvera, and R. R. Enríquez-Andrade. 2005. Rapidly shifting environmental baselines among fishers of the Gulf of California. Proceedings of the Royal Society of London B 272:1957–1962.
86. Saénz–Arroyo, A., M. R. Callum, J. Torre, and M. Cariño-Olvera. 2005. Using fishers' anecdotes, naturalists' observations, and grey literature to reassess marine species at risk: the case of the gulf grouper in the Gulf of California, Mexico. Fish and Fisheries 6:1211–1133.
87. Sánchez-Cárdenas, R. 2007. Estrategia reproductiva de *Sphoeroides annulatus* (Jenyns, 1842) (Tetraodontidae) en la costa de Mazatlán, Sinaloa, México. [Reproductive strategy of *Sphoeroides annulatus* (Jenyns, 1842) (Tetraodontidae) on the coast of Mazatlán, Sinaloa, Mexico.] Master's thesis. Centro Interdisciplinario de Ciencias Marinas–Instituto Politécnico Nacional, La Paz, Mexico.
88. Schultz, L. P. 1933. The age and growth of *Atherinops affinis oregonia* Jordon and Snyder and of other subspecies of baysmelt along the Pacific coast of the United States. University of Washington Publications in Biology 2(3):45–102.
89. Skogsberg, T. 1939. The fishes of the family Sciaenidae (croakers) of California. California Department of Fish and Game, Fish Bulletin 54.
90. Smith, S. E., and N. J. Abramson. 1990. Leopard shark *Triakis semifasciata* distribution, mortality rate, yield, and stock replenishment estimates based on a tagging study in San Francisco Bay. U.S. National Marine Fisheries Service Fishery Bulletin 88:371–381.
91. Spratt, J. D. 1986. The amazing grunion. California Department of Fish and Game, Marine Resources Leaflet 3.
92. Strategic Assessment Branch. 1990. West Coast of North America, coastal and ocean zones, strategic assessment: data atlas, prepublication edition. National Oceanic and Atmospheric Administration, Seattle.
93. Thomson, A. D., L. T. Findley, and A. N. Kerstitch. 2000. Reef fishes of the Sea of Cortez, the rocky shore fishes of the Gulf of California. University of Texas Press, Austin.
94. Thomson, J. M. 1990. Mugilidae. Pages 855–859 *in* J. C. Quero, J. C. Hureau, C. Karrer, A. Post, and L. Saldanha, editors. Checklist of the fishes of the eastern tropical Atlantic (CLOFETA), volume II. United Nations Educational, Scientific, and Cultural Organization, Lisbon, Portugal.
95. Thomson, J. M. 1963. Synopsis of biological data on the grey mullet *Mugil cephalus* Linnaeus 1758. CSIRO Fisheries and Oceanography Fisheries Synopsis 1(1–8).
96. Thomson, J. M. 1966. The grey mullets. Oceanography and Marine Biology: an Annual Review 4:301–335.
97. Torres, C. A. 1996. Aspectos biológico-pesqueros del pargo planero *Lutjanus argentiventris* (Peters 1869) y reconocimiento sobre la pesca artesanal en el municipio de Bahía Solano (Chocó-Colombia). [Biological–fishery aspects of the amarillo snapper *Lutjanus argentiventris* and description of the artisanal fishery in Solano Bay (Chocó-Colombia).] Instituto Nacional de Pesca y Acuicultura technical bulletin, Colombia.
98. Valdovinos-Jacobo, L. A. 2006. Edad, crecimiento y mortalidad de la sierra del golfo *Scomberomorus concolor* (Lockington, 1879) en el Golfo de California. [Age, growth, and mortality of the gulf sierra *Scomberomorus concolor* in the Gulf of California.] Master's thesis. Centro Interdisciplinario de Ciencias Marinas–Instituto Politécnico Nacional, La Paz, Mexico.
99. Vojkovich, M. 1992. White seabass. Pages 165–167 *in* W. S. Leet, C. M. Dewees, and C. W. Haugen, editors. California's living marine resources and their utilization. University of California–Davis, California Sea Grant Extension Program, Publication UCSGEP-92–12, Davis.
100. Walford, L. 1932. The California barracuda (*Sphyraena argentea*). California Department of Fish and Game, Fish Bulletin 37.
101. Walker, B. W. 1961. The ecology of the Salton Sea, California, in relation to the sport fishery. California Department of Fish and Game, Fish Bulletin 113.
102. Warner, R. R. 1975. The reproductive biology of the protogynous hermaphrodite *Pimelmetopon pulchrum* (Pisces: Labridae). U.S. National Marine Fisheries Service Fishery Bulletin 73:262–283.
103. Yudin, K. G. 1987. Age, growth, and aspects of the reproductive biology of two sharks, the gray smoothhound *Mustelus californicus* and the brown smoothhound *M. henlei*, from central California. Master's thesis. San Francisco State University, San Francisco, California.

Downloaded From: https://bioone.org/journals/Marine-and-Coastal-Fisheries:-Dynamics,-Management,-and-Ecosystem-Science on 29 Mar 2024
Terms of Use: https://bioone.org/terms-of-use

TABLE A.5. Species comprising the functional groups. Group names are in bold. The groups are based on an Atlantis ecosystem model by Ainsworth et al. (in press).

Gulf coney
Epinephelus acanthistius
Extranjero
Paralabrax loro
Paralabrax auroguttatus
Leopard grouper
Mycteroperca rosacea
Gulf grouper
Mycteroperca jordani
Amarillo snapper
Lutjanus argentiventris
Barred pargo
Hoplopagrus guentherii
Groupers and snappers
Pronotogrammus multifasciatus
Hemanthias peruanus
Cephalopholis panamensis
Diplectrum labarum
Pronotogrammus eos
Serranus aequidens
Liopropoma longilepis
Alphestes immaculatus
Diplectrum euryplectrum
Diplectrum macropoma
Diplectrum pacificum
Diplectrum sciurus
Alphestes afer
Epinephelus analogus
Dermatolepis dermatolepis
Epinephelus itajara
Epinephelus labriformis
Alphestes multiguttatus
Epinephelus niphobles
Epinephelus niveatus
Lutjanus aratus
Lutjanus colorado
Lutjanus guttatus
Lutjanus novemfasciatus
Lutjanus peru
Lutjanus viridis
Mycteroperca prionura
Mycteroperca xenarcha
Paralabrax maculatofasciatus
Paranthias colonus
Pseudogramma thaumasium
Rypticus bicolor
Rypticus nigripinnis
Serranus fasciatus
Serranus psittacinus
Drums and croakers
Atractoscion nobilis
Bairdiella icistia
Cheilotrema saturnum
Cynoscion parvipinnis
Umbrina roncador
Ophioscion scierus
Odontoscion xanthops
Micropogonias megalops
Micropogonias ectenes
Micropogonias altipinnis
Menticirrhus nasus
Larimus effulgens
Larimus argenteus
Larimus acclivis
Isopisthus remifer
Elattarchus archidium
Cynoscion othonopterus
Cynoscion nannus
Ophioscion strabo
Stellifer illecebrosus
Umbrina wintersteeni
Umbrina xanti
Corvula macrops
Cynoscion squamipinnis
Bairdiella armata
Cynoscion reticulatus
Cynoscion xanthulus
Larimus pacificus
Menticirrhus undulatus
Grunts
Anisotremus interruptus
Conodon serrifer
Anisotremus caesius
Anisotremus davidsonii
Anisotremus dovii
Anisotremus taeniatus
Haemulon flaviguttatum
Haemulon maculicauda
Haemulon scudderii
Haemulon sexfasciatum
Haemulon steindachneri
Microlepidotus inornatus
Orthopristis chalceus
Orthopristis reddingi
Pomadasys panamensis
Xenistius californiensis
Herbivorous fish
Acanthurus xanthopterus
Prionurus punctatus
Acanthurus achilles
Acanthurus nigricans
Calotomus spinidens
Girella nigricans
Hermosilla azurea
Mugil cephalus
Mugil curema
Nicholsina denticulata
Scarus compressus
Scarus ghobban
Scarus perrico
Scarus rubroviolaceus
Large reef fish
Acanthurus triostegus
Balistes polylepis
Pseudobalistes naufragium
Sufflamen verres
Chlopsis kazuko
Gorgasia punctata
Heteroconger canabus
Heteroconger digueti
Ariosoma gilberti
Paraconger similis
Paraconger californiensis
Bathycongrus macrurus
Bathycongrus varidens
Gnathophis cinctus
Rhynchoconger nitens
Thalassoma lucasanum
Nemichthys larseni
Myrichthys maculosus
Myrophis vafer
Ophichthus triserialis
Ophichthus zophochir
Callechelys cliffi
Callechelys eristigma
Ethadophis byrnei
Apterichtus gymnocelus
Brotula clarkae
Lepophidium microlepis
Lepophidium negropinna
Lepophidium pardale
Lepophidium prorates
Lepophidium stigmatistium
Petrotyx hopkinsi
Neobythites stelliferoides
Regalecus glesne

Downloaded From: https://bioone.org/journals/Marine-and-Coastal-Fisheries:-Dynamics,-Management,-and-Ecosystem-Science on 29 Mar 2024
Terms of Use: https://bioone.org/terms-of-use

TABLE A.5. Continued.

Sebastes diploproa
Sebastes macdonaldi
Sebastes sinensis
Sebastes cortezi
Sebastes exsul
Trichiurus lepturus
Bodianus diplotaenia
Decodon melasma
Halichoeres aestuaricola
Halichoeres chierchiae
Halichoeres dispilus
Halichoeres nicholsi
Halichoeres notospilus
Halichoeres semicinctus
Lobotes pacificus
Nematistius pectoralis
Pareques fuscovittatus
Pareques viola
Pseudojuloides inornatus
Halichoeres melanotis
Semicossyphus pulcher
Stereolepis gigas
Thalassoma lutescens
Thalassoma purpureum

Small reef fish

Antennarius sanguineus
Apogon retrosella
Ablennes hians
Hypsoblennius brevipinnis
Entomacrodus chiostictus
Grammonus diagrammus
Acanthemblemaria balanorum
Acanthemblemaria crockeri
Coralliozetus angelicus
Coralliozetus micropes
Cirriemblemaria lucasana
Protemblemaria bicirrus
Prognathodes falcifer
Forcipiger flavissimus
Chaetodon humeralis
Johnrandallia nigrirostris
Cirrhitichthys oxycephalus
Oxycirrhites typus
Cirrhitus rivulatus
Diodon hystrix
Diodon holocanthus
Chaetodipterus zonatus
Fistularia commersonii
Arcos erythrops
Gobiesox adustus
Tomicodon humeralis
Tomicodon zebra
Gobiosoma paradoxum
Kyphosus elegans
Paraclinus altivelis
Xenomedea rhodopyga
Uropterygius macrocephalus
Gymnomuraena zebra
Muraena lentiginosa
Echidna nocturna
Enchelycore octaviana
Gymnothorax castaneus
Gymnothorax dovii
Gymnothorax panamensis
Muraena argus
Muraena clepsydra
Holacanthus passer
Pomacanthus zonipectus
Abudefduf troschelii
Chromis atrilobata
Abudefduf concolor
Chromis alta
Chromis limbaughi
Microspathodon bairdii
Microspathodon dorsalis
Stegastes leucorus
Stegastes rectifraenum
Abudefduf declivifrons
Synodus lucioceps
Sphoeroides annulatus
Arothron meleagris
Canthigaster punctatissima
Enneanectes carminalis
Zanclus cornutus
Acanthemblemaria macrospilus
Aluterus scriptus
Apogon atricaudus
Apogon dovii
Apogon pacificus
Arothron hispidus
Bathygobius ramosus
Cosmocampus arctus arctus
Cantherhines dumerilii
Caulolatilus princeps
Chilomycterus affinis
Coralliozetus rosenblatti
Doryrhamphus excisus excisus
Elacatinus digueti
Elacatinus puncticulatus
Stegastes flavilatus
Stegastes redemptus
Gobiosoma chiquita
Gobiosoma nudum
Gobulus hancocki
Gymneleotris seminuda
Hippocampus ingens
Holacanthus clarionensis
Hypsypops rubicundus
Kuhlia mugil
Labrisomus multiporosus
Labrisomus xanti
Lactoria diaphana
Lythrypnus pulchellus
Malacoctenus gigas
Medialuna californiensis
Mnierpes macrocephalus
Mulloidichthys dentatus
Myripristis leiognathus
Ogilbia ventralis
Ophioblennius steindachneri
Opistognathus scops
Paraclinus mexicanus
Parapsettus panamensis
Plagiotremus azaleus
Heteropriacanthus cruentatus
Pristigenys serrula
Pycnomma semisquamatum
Uropterygius polystictus
Scuticaria tigrina
Malacoctenus tetranemus
Ostracion meleagris

Small demersal fish

Albula vulpes
Bajacalifornia burragei
Phthanophaneron harveyi
Antennarius avalonis
Antennatus strigatus
Notarius planiceps
Hexanematichthys platypogon
Bagre pinnimaculatus
Notarius troschelii
Aulopus bajacali
Porichthys analis
Porichthys ephippiatus

Downloaded From: https://bioone.org/journals/Marine-and-Coastal-Fisheries:-Dynamics,-Management,-and-Ecosystem-Science on 29 Mar 2024
Terms of Use: https://bioone.org/terms-of-use

TABLE A.5. Continued.

Porichthys mimeticus
Strongylura exilis
Platybelone argalus pterura
Tylosurus pacificus
Tylosurus crocodilus fodiator
Hypsoblennius gentilis
Hypsoblennius jenkinsi
Hypsoblennius digueti
Bregmaceros bathymaster
Cataetyx rubrirostris
Carapus dubius
Echiodon exsilium
Centropomus nigrescens
Centropomus medius
Centropomus viridis
Centropomus robalito
Ekemblemaria myersi
Emblemaria hypacanthus
Emblemaria walkeri
Stathmonotus sinuscalifornici
Chaenopsis coheni
Coralliozetus boehlkei
Dactyloscopus pectoralis
Gillellus semicinctus
Dactylagnus mundus
Dactyloscopus byersi
Gillellus ornatus
Myxodagnus macrognathus
Chilomycterus reticulatus
Zalembius rosaceus
Fistularia corneta
Rimicola eigenmanni
Rimicola dimorpha
Tomicodon eos
Tomicodon boehlkei
Gobiesox pinniger
Gobiesox schultzi
Tomicodon myersi
Rimicola sila
Aruma histrio
Barbulifer mexicanus
Barbulifer pantherinus
Bollmannia stigmatura
Bollmannia macropoma
Bollmannia longipinnis
Bollmannia ocellata
Bollmannia pawneea
Evermannia longipinnis
Gillichthys seta
Elacatinus limbaughi
Ilypnus luculentus
Ophiodon elongatus
Oxylebius pictus
Zaniolepis frenata
Sargocentron suborbitalis
Exerpes asper
Paraclinus tanygnathus
Starksia spinipenis
Cryptotrema seftoni
Labrisomus wigginsi
Paraclinus beebei
Starksia cremnobates
Paraliparis ulochir
Psednos pallidus
Psednos griseus
Caelorinchus scaphopsis
Neoconger vermiformis
Gymnothorax mordax
Anarchias galapagensis
Gymnothorax equatorialis
Gymnothorax verrilli
Gymnothorax eurygnathos
Eptatretus mcconnaugheyi
Eptatretus sinus
Barbantus curvifrons
Mentodus eubranchus
Synodus sechurae
Lagocephalus lagocephalus
Sphoeroides sechurae
Sphoeroides lispus
Lycenchelys folletti
Axoclinus nigricaudus
Bollmannia marginalis
Calamus brachysomus
Caulolatilus hubbsi
Chaenopsis alepidota alepidota
Chriolepis minutillus
Chriolepis zebra
Coryphopterus urospilus
Crocodilichthys gracilis
Ctenogobius sagittula
Dactyloscopus lunaticus
Enypnias seminudus
Gillichthys mirabilis
Girella simplicidens
Gobiesox papillifer
Gobulus crescentalis
Kathetostoma averruncus
Kyphosus analogus
Labrisomus striatus
Lythrypnus dalli
Malacoctenus ebisui
Malacoctenus hubbsi
Malacoctenus margaritae
Malacoctenus zacae
Malacoctenus zonifer
Microgobius cyclolepis
Myxodagnus opercularis
Opistognathus punctatus
Opistognathus rhomaleus
Paraclinus sini
Pherallodiscus funebris
Quietula y-cauda
Sectator ocyurus
Sphoeroides lobatus
Starksia grammilaga
Starksia hoesei
Synodus scituliceps

Pacific angel shark

Squatina californica

Small migratory sharks

Mustelus dorsalis
Mustelus henlei
Mustelus lunulatus
Mustelus californicus

Large pelagic sharks

Alopias superciliosus
Carcharhinus limbatus
Carcharhinus porosus
Ginglymostoma cirratum
Alopias pelagicus
Alopias vulpinus
Carcharhinus leucas
Carcharhinus obscurus
Carcharodon carcharias
Isurus oxyrinchus
Rhizoprionodon longurio
Sphyrna lewini
Sphyrna mokarran
Sphyrna zygaena

Guitarfish

Platyrhinoidis triseriata
Zapteryx exasperata
Rhinobatos leucorhynchus

Downloaded From: https://bioone.org/journals/Marine-and-Coastal-Fisheries:-Dynamics,-Management,-and-Ecosystem-Science on 29 Mar 2024
Terms of Use: https://bioone.org/terms-of-use

TABLE A.5. Continued.

Rhinobatos glaucostigma
Rhinobatos productus
Skates, rays and sharks
Hydrolagus colliei
Dasyatis brevis
Gymnura marmorata
Gymnura crebripunctata
Heterodontus francisci
Heterodontus mexicanus
Aetobatus narinari
Myliobatis californica
Mobula thurstoni
Narcine entemedor
Diplobatis ommata
Apristurus kampae
Cephaloscyllium ventriosum
Triakis semifasciata
Urobatis halleri
Urotrygon chilensis
Urobatis concentricus
Urobatis maculatus
Urotrygon rogersi
Dasyatis dipterura
Myliobatis longirostris
Raja equatorialis
Rhinoptera steindachneri
Flatfish
Achirus mazatlanus
Achirus scutum
Trinectes fonsecensis
Bothus constellatus
Bothus leopardinus
Perissias taeniopterus
Symphurus atricaudus
Symphurus atramentatus
Symphurus callopterus
Symphurus chabanaudi
Symphurus fasciolaris
Symphurus gorgonae
Symphurus leei
Symphurus melanurus
Symphurus oligomerus
Symphurus prolatinaris
Symphurus williamsi
Symphurus elongatus
Paralichthys aestuarius
Citharichthys mariajorisae
Ancylopsetta dendritica
Citharichthys fragilis
Citharichthys stigmaeus
Citharichthys xanthostigma
Etropus crossotus
Hippoglossina bollmani
Hippoglossina stomata
Paralichthys californicus
Paralichthys woolmani
Pleuronichthys ocellatus
Pleuronichthys verticalis
Syacium ovale
Xystreurys liolepis
Mojarra
Gerres cinereus
Diapterus peruvianus
Eugerres axillaris
Eucinostomus currani
Eucinostomus entomelas
Diapterus aureolus
Scorpionfish
Pontinus sierra
Scorpaena sonorae
Bellator xenisma
Prionotus stephanophrys
Bellator loxias
Prionotus albirostris
Prionotus birostratus
Prionotus ruscarius
Scorpaena guttata
Scorpaena histrio
Scorpaena mystes
Scorpaena plumieri
Scorpaena russula
Scorpaenodes xyris
Lanternfish and deep
Triphoturus mexicanus
Benthosema panamense
Lampanyctus parvicauda
Zalieutes elater
Dibranchus hystrix
Dibranchus spinosus
Chauliodus macouni
Stomias atriventer
Bathophilus filifer
Totoaba
Totoaba macdonaldi
Large pelagics
Naucrates ductor
Caranx caballus
Caranx caninus
Carangoides otrynter
Caranx sexfasciatus
Caranx vinctus
Chloroscombrus orqueta
Decapterus macrosoma
Hemicaranx leucurus
Hemicaranx zelotes
Trachinotus kennedyi
Trachinotus paitensis
Trachinotus rhodopus
Gnathanodon speciosus
Coryphaena hippurus
Remora remora
Elops affinis
Lampris guttatus
Mola mola
Ranzania laevis
Physiculus nematopus
Rhincodon typus
Oncorhynchus tshawytscha
Katsuwonus pelamis
Auxis rochei eudorax
Auxis thazard brachydorax
Sphyraena lucasana
Peprilus ovatus
Peprilus snyderi
Xiphias gladius
Euthynnus lineatus
Oligoplites altus
Sarda chiliensis chiliensis
Seriola lalandi
Seriola rivoliana
Sphyraena ensis
Elagatis bipinnulata
Mackerel
Trachurus symmetricus
Gempylus serpens
Scomberomorus concolor
Scomber japonicus
Scomberomorus sierra
Hake
Merluccius angustimanus
Merluccius hernandezi
Small pelagics
Argentina sialis
Atherinops affinis

Downloaded From: https://bioone.org/journals/Marine-and-Coastal-Fisheries:-Dynamics,-Management,-and-Ecosystem-Science on 29 Mar 2024
Terms of Use: https://bioone.org/terms-of-use

TABLE A.5. Continued.

Colpichthys regis
Atherinella eriarcha
Atherinella nepenthe
Colpichthys hubbsi
Leuresthes sardina
Bathylagus stilbius
Sardinops sagax
Harengula thrissina
Opisthonema libertate
Lile stolifera
Pliosteostoma lutipinnis
Opisthopterus dovi
Anchoa curta
Anchoa walkeri
Anchovia macrolepidota
Cetengraulis mysticetus
Anchoa mundeoloides
Anchoa mundeola
Anchoa ischana
Anchoa exigua
Anchoa nasus
Anchoa argentivittata
Anchoa helleri
Cheilopogon pinnatibarbatus
Cypselurus callopterus

Mysticeti

Balaenoptera edeni
Balaenoptera physalus
Balaenoptera musculus
Eschrichtius robustus
Megaptera novaeangliae

Odontocetae

Delphinus capensis
Delphinus delphis
Tursiops truncatus
Lagenorhynchus obliquidens
Berardius bairdii
Physeter macrocephalus
Globicephala macrorhynchus
Pseudorca crassidens
Mesoplodon peruvianus

Vaquita

Phocoena sinus

Pinnipeds

Mirounga angustirostris
Zalophus californianus

Reef associated turtles

Caretta caretta
Eretmochelys imbricata
Chelonia mydas

Sea birds

Sula nebouxii
Sula leucogaster
Larus heermanni
Larus californicus
Larus livens
Thalasseus elegans
Thalasseus maximus
Sterna forsteri
Oceanodroma melania
Halocyptena microsoma
Phalacrocorax penicillatus
Phalacrocorax auritus
Fregata magnificens
Haematopus palliatus
Egretta thula
Egretta rufescens
Ardea alba
Ardea herodias
Numenius phaeopus
Calidris minutilla
Arenaria melanocephala
Pelecanus occidentalis
Puffinus griseus
Puffinus carneipes
Podiceps nigrocollis
Synthliboramphus craveri

Squid

Dosidicus gigas
Argonauta argo
Histioteuthis hoylei
Loliolopsis diomedeae
Ommastrephes bartramii
Pterygiotheuthis giardigiardi
Sthenoteuthis oualaniensis
Thysanoteuthis rhombus

Blue crab

Callinectes bellicosus
Callinectes arcuatus
Callinectes toxotes

Scallops and penshells

Spondylus calcifer
Spondylus princeps
Pteria sterna
Pinna rugosa
Atrina tuberculosa
Pinctada mazatlanica

Penaeid shrimp

Penaeus aztecus
Penaeus duorarum
Penaeus setiferus
Sicyonia penicillata

Lobster

Panulirus interruptus
Panulirus inflatus
Panulirus gracilis

Crabs and lobsters

Callinectes spp.[a]
Panulirus spp.[a]

Carnivorous macrobenthos

Class Polyplacophora

Class Asteroidea
Class Ophiuroidea
Class Cephalopoda, order Octopoda
Class Gastropoda, order Nudibranchia

Sea cucumbers

Class Holothuroidea

Bivalves

Class Pelecypoda

Snails

Class Gastropoda

[a]Species not included elsewhere.

Downloaded From: https://bioone.org/journals/Marine-and-Coastal-Fisheries:-Dynamics,-Management,-and-Ecosystem-Science on 29 Mar 2024
Terms of Use: https://bioone.org/terms-of-use

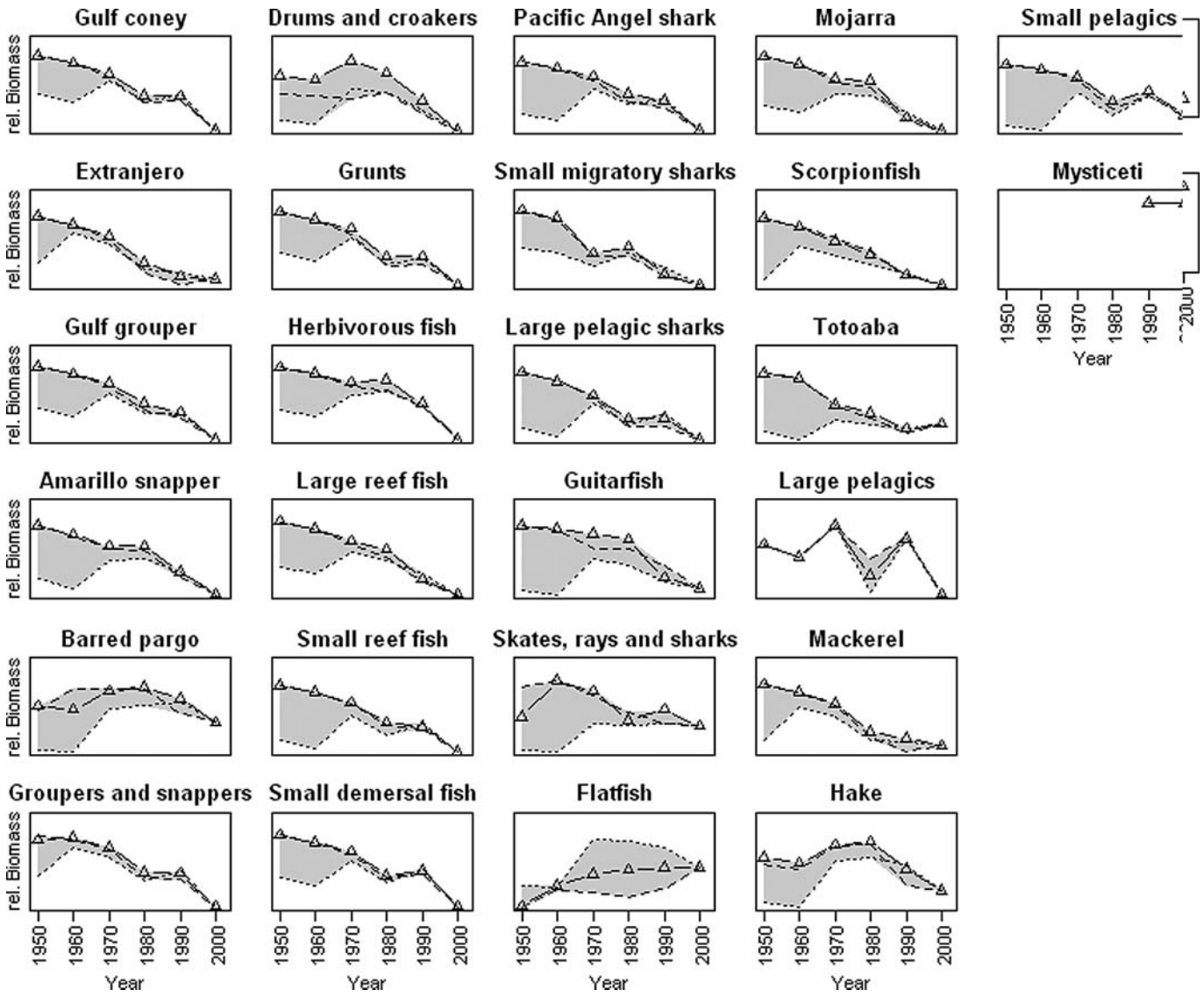


FIGURE A.1. Abundance of functional groups predicted by the fuzzy logic algorithm based on abundance indicators only (see text). Triangles show the results when the responses from all fishers are included in the algorithm, dotted lines the results when only young (below the median age of 43) fishers' responses are included, dashed lines the results when only older fishers' responses are included. The shaded areas show the total potential range (minimum–maximum) of all series. Trends have been scaled to agree in the year 2000. Species groups that had at least eight respondents are shown.

Downloaded From: https://bioone.org/journals/Marine-and-Coastal-Fisheries:-Dynamics,-Management,-and-Ecosystem-Science on 29 Mar 2024
Terms of Use: https://bioone.org/terms-of-use