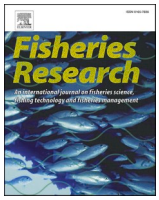
Fisheries Research 285 (2025) 107362

Contents lists available at ScienceDirect

Fisheries Research

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



Socio-economic status and occupational mobility of China's Fishery Population: A quantitative analysis based on social-survey data

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ARTICLE INFO

Keywords:
Fishery population
Socio-economic status
Occupational mobility

ABSTRACT

China ranks as the first fishery nation globally in terms of its fishery production, with a total production of more than 67 million metric tons in 2022. More than 16 million people work in and earn their livelihoods from fisheries, directly or indirectly. A better understanding of the characteristics of this large group of people could lead to an improved appreciation of the human dimensions of China's fisheries. In this study, we analyze longitudinal social-survey data from 1989 to 2015 to derive several key indicators representing the socio-economic status of China's fishery population. We find that, first, the size of the fishery population is shrinking. Second, the average age of the fishery population is increasing but at a slower rate than in the total population. Third, the education levels of the fishery population are rising but remain below those of urban residents. Fourth, the incomes of the fishery population have grown considerably, albeit more slowly than those of the general rural population and the urban population. Fifth, the employment of the fishery population is exhibiting a high degree of dynamism, with high rates of occupational mobility between the fishing sector and other sectors.

1. Introduction

The world's total fisheries and aquaculture production amounted to 185 million metric tons in 2022, with China – at 36 percent of the total – being the largest producer (FAO, 2024). The fishing industry in China is a significant source of livelihoods and employment: there are about 132, 290 marine vessels engaged in capture fishing and 11.8 million employees (53.5 % full-time, 33.8 % part-time, and 12.7 % temporary workers) in the Chinese fishing industry, including 1.2 million full-time fishing employees working in capture fishing (Ministry of Agriculture Bureau of Fisheries, 2022).

The human dimensions of fisheries refer to multiple components, including but not limited to human well-being, cultural heritage, social and economic circumstances, sustainable livelihoods, and governance (Kaplan and McCay, 2004; Weeratunge et al., 2014; Barreto et al., 2020; Szymkowiak, 2021). Data to study these issues are usually obtained through social surveys of individuals or communities using interviews or questionnaires. In-depth interview-based surveys typically have a narrow geographic scope, focusing on single communities or smaller regions (Macusi et al., 2015; Voyer et al., 2017; Thomas Travaille et al., 2019; Turner et al., 2024), whereas the ones with broader geographic scope tend to have a narrow temporal scope or focus on single issues (Teh et al., 2017). Questionnaire-based surveys allow simultaneously covering broader geographic areas and a wider range of issues, including health, demographics, income, and education, but, in terms of temporal coverage, the datasets used in these studies are either snapshots or cover only a short timespan (Tzanatos et al., 2006; Pita et al., 2010; Syda Rao et al., 2016; Turner et al., 2019; Anna et al., 2019; Holland et al., 2020; Speir et al., 2020; Evoy and Case, 2022; Doza et al., 2022), with a resulting lack of a longitudinal perspective.

The literature on the human dimensions of Chinese fisheries is large and diverse but, like in other jurisdictions, tends to be based on studies that have a narrow thematic scope and limited geographic or temporal coverage. For example, there are several studies on specific topics such

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https://doi.org/10.1016/j.fishres.2025.107362
Received 9 November 2022; Received in revised form 4 March 2025; Accepted 31 March 2025
Available online 6 April 2025

as the incomes of China's fishery population and their families (Zhao and Wang, 2006; Jiang et al., 2012; Tong et al., 2013a; Cheng et al., 2016; Yue et al., 2017), the occupational mobility of the marine-fishery population (Song, 2007; Tang, 2011; Wang, 2012, 2018; Tong and Huang, 2013; Liu, 2014), and the differentiation of vocations in the marine-fishery population (Cui, 2008; Lin, 2010; Tang, 2010; Zhang, 2012; Huang, 2014) and among those who have left the fishing industry (Yin, 2009; Tong et al., 2013b). A complementary line of research has been focused on the theory of management, policy, and development (e.g., Liu, 2006; Han et al., 2007). Within this body of research, qualitative studies have mostly been conducted in particular Chinese provinces or fishing villages (Lin, 2010; Tang, 2010; Zhang, 2012; Liu, 2014; Wang, 2018). Nationwide quantitative studies are usually based on highly aggregated statistical data published by the government, which describe nationwide features but cannot account for individual-level aspects (Song, 2007; Cui, 2008; Wang, 2012). Considering the temporal coverage, most studies are based on snapshots or very short time periods, typically less than five years (Song, 2007; Cui, 2008; Lin, 2010; Tang, 2010; Wang, 2012, 2018; Zhang, 2012; Liu, 2014).

China Health and Nutrition Survey (CNHS) is an ongoing longitudinal social survey that has been conducted since 1989 at intervals of a few years (CHNS Project, 2018a). The CNHS data offer good geographic coverage and a rich array of information on demography, education, income, and occupational activity. The survey covers a period of fast-paced economic and social change in China. Until now, however, the potential of this survey to elucidate social and economic changes in China's fishery population have remained unutilized.

Here we use individual-level data from the CNHS from 1989 until 2015 to describe and understand social and economic changes in China's fishery population. We combine descriptive statistics derived from the CHNS data with national statistics to characterize changes in China's fishery population and how these changes compare to nationwide developments. Our research is intended to elucidate the following three main questions: What is the demographic and socio-economic status of China's fishery population, and how has it changed over time? What is the occupational mobility of China's fishery population, and how has it changed over time? How do the corresponding indicators and trends in China's fishery population compare to those in China's total population? We find that China's fishery population is shrinking, aging, but also characterized by high mobility between the fishery sector and other sectors. Although incomes and educational level of China's fishery population have been steadily increasing, they have done so slower than in the general population, leading to a relative decline in the social standing of China's fishery population.

2. Materials and methods

2.1. China Health and Nutrition Survey

The China Health and Nutrition Survey (CHNS) is an ongoing nationwide survey that consistently covers content related to fishery and fishing over an extended time period (Section A1 in the Appendix). It is a questionnaire-based, longitudinal social survey, whose main purpose is to show how China's social and economic development affects the health and nutrition of its population (CHNS Project, 2018b). In the present study, we use data from the ten first surveys (also called 'survey waves'), conducted in 1989, 1991, 1993, 1997, 2000, 2004, 2006, 2009, 2011, and 2015. The survey took place in 12 provinces and municipal cities that vary substantially in their geography, level of economic development, available common resources, and health indicators (CHNS Project, 2018c). These provinces and municipal cities, including five coastal ones indicated here with an asterisk, are: Beijing, Chongqing, Guangxi* , Guizhou, Heilongjiang, Henan, Hubei, Hunan, Jiangsu* , Liaoning* , Shandong* , and Shanghai* . The latest survey was conducted in 2019, but by 2025, the resultant data were not yet publicly available (the CHNS website indicates the 2019 data collection as being "underway").

The CHNS Project used a multistage random cluster process to draw a total sample of about 15,000 individual respondents in each survey year (Table 1). In each of the surveyed provinces, four counties and two cities are included (Section A2 of the Appendix; Popkin et al., 2010). Within these units, random individuals have been chosen for the survey. As far as possible, the same individuals have been followed over the survey years. Respondents dropping out from the survey were replaced with new ones; see Table A2 in the Appendix for further information on respondent retention.

The CHNS includes three components: individual survey, household survey, and community survey. The component most relevant for our current study is the individual survey, which covers individual-level economic, demographic, and social factors. The individual-survey questionnaire consists of eleven parts, of which three – entitled *Demographics*, *Work activities*, and *Income* – include indicators of interest for the present study. Each part contains several topics, and each topic includes several questions addressing a respondent's status during the calendar year prior to the survey year. The CHNS's structure and content are summarized in Figure A1 in the Appendix.

We identified the subset of respondents who can be classified as representing the fishery population based on fishery-related questions in the household survey and the individual survey. In the individual-survey questionnaire, the *Income* part contains the topic 'Collective and household fishing', which in turn includes a series of second-level questions related to a respondent's activities in household and collective fishing, beginning with the first-level question "Did you work in fishing either in a collective or in a business operated by your household last year?". We considered respondents with affirmative answers to any of these questions as representing the fishery population and extracted the data corresponding to these households and individuals from the CHNS database. There were 1016 respondents from 10 survey years in this subset of fishery respondents (Table 1), representing 645 unique individuals with ages from 8 to 75 years. Changes in the number of the fishery respondents across survey years are documented in Table A3 in the Appendix.

2.2. Demographic and socio-economic indicators

We describe the fishery population in terms of five demographic and socio-economic dimensions: population size, age structure, education level, income, and occupational mobility. Combining the CHNS data with other data sources outlined below and detailed in Section A5 of the Appendix, we determine a number of key indicators that describe the changes in the fishery population over time, both relative to the fishery population in the beginning of the survey and relative to China's population as a whole.

2.2.1. Population size

For each survey year, we analyze two indicators, (a) the nationwide total size of the fishery population and (b) the proportion of the fishery population as a percentage of China's total population. We estimate these indicators in four different ways as described below.

First, we estimate indicator (a) from the CHNS and extrapolate this result to indicator (b) by using the rule of proportions, i.e., by multiplying the CHNS-based proportion of the fishery population as a percentage of China's total population with China's total population size (from the China Statistical Yearbook; National Bureau of Statistics of China, 2020).

Second, we compare these results for indicators (a) and (b) according to the CHNS to those for three alternative definitions of the fishery population according to the China Fisheries Yearbook (CFY; Ministry of Agriculture Bureau of Fisheries, 2020): (1) the fishery population according to the CFY, (2) the population of fishery practitioners, also known as the fishery labor force, and (3) the traditional-fishery population. The population of fishery practitioners and the traditional-fishery

Table 1
Number of respondents in the China Health and Nutrition Survey (CHNS) and number of respondents reporting fishery activity in each of ten survey years (CHNS Project, 2018c).

Year	1989	1991	1993	1997	2000	2004	2006	2009	2011	2015	Total
Survey respondents	15,907	14,797	13,895	14,441	15,831	12,308	11,860	12,178	15,725	16,622	143,564
Fishery respondents	125	101	85	131	126	110	105	76	90	67	1016

population are partially overlapping subsets of the fishery population according to the CFY. The fishery population according to the CFY also includes the dependents of fishery practitioners and persons not living in fishery townships and villages. These three alternative definitions are explained in more detail in Section A4 of the Appendix.

2.2.2. Age

In the *Demographics* part of the CHNS individual survey, two questions address the age of respondents: "Date of birth (western calendar/lunar calendar)" and "Your age". Based on cross-checking and processing the answers to these questions, the dataset released by the CHNS Project specifies the age of each respondent: in the present study, we thus use this quantity to analyze the age characteristics of the fishery population. For each survey year, we tabulate respondents according to their age and gender to determine age distributions, mean ages, and trends over time. To better visualize the resultant age distributions, we smooth them using a Gaussian kernel density estimate based on Silverman's rule, i.e., with the bandwidth of the Gaussian smoothing kernel set to 0.9 times the minimum of the data's standard deviation and interquartile range divided by 1.34, times the data's sample size raised to the negative one-fifth power (Silverman, 1986).

To compare these results with China's total population, we calculate for each survey year the ratio between the mean age of the fishery population and the mean age of China's total population according to the CHNS. To describe aging in the fishery population and China's total population, we also use the proportions of population aged 65 years or older. We calculate these indicators for all survey respondents, rural respondents, and urban respondents (with the latter two defined as respondents who were residing, respectively, in rural or urban areas at the time of their participation in the survey), as listed in Table A5 in the Appendix.

2.2.3. Education

In the *Demographics* part of the CHNS individual survey, two questions address the education of respondents: "How many years of formal education have you completed in a regular school?" and "What is the highest level of education you have attained?". Since the first question has not been used in some of the survey years, we use the answers to the second question. For each survey year, we determine two indicators. First, we calculate the proportion of each level of education. Second, we convert this indicator from the level of education to the corresponding number of education years according to a recoding rule explained in Section A2 of the Appendix. We calculate these indicators for all survey respondents, rural respondents, and urban respondents, as listed in Table A6 in the Appendix.

2.2.4. Income

In the *Income* part of the CHNS individual survey, a series of questions address the income of respondents. Based on the answers to these questions, the dataset released by the CHNS Project specifies a set of variables constructed to describe the income of individual respondents, with the underlying definitions reported in the codebook of the CHNS (CHNS Project, 2018d): in the present study, we use one of these constructed variables, the "Total net individual income inflated to 2015", to analyze the income characteristics of the fishery population. We assess trends in the distribution of this variable using as indicators its median, quartiles, and 1 % and 99 % quantiles. We calculate these indicators for all survey respondents, rural respondents, and urban respondents, as listed in Table A7 in the Appendix.

2.2.5. Occupational mobility

In the present study, we consider two occupational sectors – fishing and non-fishing – based on whether or not respondents are in the fishery population (i.e., reporting fishing activity) during a survey year. Below we use N to denote respondents who are not in the fishery population and F to denote respondents who are in the fishery population during a survey year. We assess occupational mobility by comparing the occupational sector of respondents across two or three consecutive surveys.

When two consecutive surveys are used to assess occupational mobility, we compare the occupational sectors of respondents in the considered survey year with those in the previous survey year. Respondents with the pattern F → F, where the arrow is indicating the transition from the previous survey year to the considered survey year, are classified as "Stayed". Similarly, those with patterns N → F and F → N are classified as "Joined" and "Left", respectively. In this way, the occupational mobility patterns of respondents are divided into three classes, and we can calculate the proportions of these classes for each survey year beyond the first. Examining the data in this way, we find that it is common for individuals repeatedly to change their occupational sector between consecutive survey years. To analyze this type of mobility further, occupational mobility patterns of respondents need to be considered over three consecutive surveys.

When three consecutive surveys are used to assess occupational mobility, we compare the occupational sectors of respondents in the considered survey year with the two previous survey years. Respondents with the pattern F → F → F are classified as "Stayed". Those with patterns N → N → F or N → F → F are classified as "Joined". Those with patterns F → N → N or F → F → N are classified as "Left". Some respondents changed their occupational sectors twice during the considered three survey years: those with the pattern N → F → N are classified as "Joined-and-left", and those with the pattern F → N → F are classified as "Left-and-joined". In this way, the occupational mobility patterns of respondents are divided into five classes, and we can calculate the proportions of these classes for each survey year beyond the second.

A complementary way to describe occupational mobility is to calculate how long respondents remain in the fishery population. Since the time intervals between consecutive survey years are not identical and since no observations were made between survey years, we parsimoniously assume that a respondent's fishing activity in a survey year applies from the midpoint between the previous survey year and the considered survey year to the midpoint between the considered survey year and the next survey year. Using this information, we consider three alternative quantitative measures of the duration of engagement in the fishing sector. First, the *continual duration* is the length of time of each continual period for which a respondent reported fishing activity. Second, the *summed duration* is the total length of time for which a respondent reported fishing activity across all survey years, which equals the sum of all continual durations for that respondent. Third, the *total duration* is the length of time from the first to the last survey for which a respondent reported fishing activity, which exceeds the summed duration by the sum of all intermediate gaps in fishing activity for that respondent. Figure A2 in the Appendix illustrates the differences among the definitions of these three measures with an example.

To assess the occupational mobility of the survey population in comparison with the fishery population, we use the question "What is your primary occupation" in the *Work Activities* part of the CHNS

individual survey. Respondents who changed their primary occupation from the previous survey year to the considered survey year are classified as "Left", whereas respondents who reported the same primary occupation in both survey years are classified as "Stayed". In this way, the occupational mobility patterns of respondents are divided into two classes, and we can calculate the proportions of these classes for each survey year beyond the first.

2.2.6. Deriving population-level indicators from survey-level data

The calculation of population-level indicators needs to account for the survey design. While the CHNS Project has not published sampling weights that would fully account for the CHNS design (Popkin et al., 2010), we can account for the varying sampling intensities between different provinces in each survey year with data available on the sizes of the fishery population and of the total population in each province. We construct the survey weights using the post-stratification weighting method with auxiliary data to correct for coverage differences between the geographic distribution groups. This is a common technique widely employed in survey analyses for inferring the population distribution of variables from survey-based estimates by combining data collected in a survey with aggregated data on the population from other sources (Holt and Smith, 1979; Smith, 1991; Lohr, 2021; Ben-Michael et al., 2024).

For indicators describing the total population of China, we use the total-population estimates per province from the annual editions of the China Statistical Yearbook (CSY; National Bureau of Statistics of China, 1989–2020) to account for sampling-intensity variation in the CHNS total sample. For indicators describing the fishery population in China, we use the province-level data from the annual editions of the China Fisheries Yearbook (CFY; Ministry of Agriculture Bureau of Fisheries, 1989–2020) to account for sampling-intensity variation in the CHNS fishery sample. Of the three alternative ways of delineating the fishery population in the China Fisheries Yearbooks (Section 2.3.1), we choose the population of fishery practitioners because it most closely matches the fishery respondents in the CHNS data. The China Fisheries Yearbooks do not disaggregate the fishery population in dimensions other than the province dimension, thereby precluding the development of a more refined weighting of the CHNS data.

We calculate survey weights separately for the indicators describing the total population of China and for the indicators describing the fishery population in China, by considering either the CHNS total sample in relation to China's total population or the CHNS fishery sample in relation to China's fishery population. In a first step, we calculate the proportion $p_{i,j}$ of the population in province i in year j among the nationwide population in year j, based on data from either the CSY or the CFY, depending on the indicator. In a second step, analogous proportions are calculated using the CHNS data, with $s_{i,j}$ denoting the proportion of survey respondents in province i in year j among the nationwide survey respondents in year j, based on data from either the CHNS total survey respondents or the CHNS fishery population respondents, depending on the indicator. In a third step, the survey weight of a CHNS respondent in province i in year j is calculated as $w_{i,j} = p_{i,j}/s_{i,j}$. A survey weight less than 1 indicates that a province was over-represented in the survey in that year and that the corresponding respondents therefore need to be down-weighted to obtain unbiased population estimates, whereas a survey weight larger than 1 indicates under-representation and the need for up-weighting. Section A8 of the Appendix shows maps of $p_{i,j}$, $s_{i,j}$, and $w_{i,j}$ for both total and fishery population samples, all provinces, and all survey years.

Since indicators describing occupational mobility combine data from two or more surveys (Section 2.3.5), the survey weight of a respondent's occupational transition is calculated using the geometric mean of the respondent's survey weights in the corresponding survey years. Specifically, the survey weight of a respondent's two-survey transition from survey year j' to survey year j in province i is given by $w'_{i,j} = \sqrt[2]{w_{i,j'} w_{i,j}}$. Analogously, the survey weight of a respondent's three-survey transition from survey year j'' to survey year j' to survey year j in province i is given by $w''_{i,j} = \sqrt[3]{w_{i,j''} w_{i,j'} w_{i,j}}$. Figure A2 in the Appendix provides an example.

For indicators that have no natural upper bound (i.e., all indicators except those that are proportions), the weighted mean values and corresponding 95 % confidence intervals are calculated using year-specific weighted linear models of the type $x_{j,k} \sim x_j$, where $x_{j,k}$ is the indicator value of individual k in year j and x_j is the estimated mean value $x_j = \sum_k x_{j,k} w_{i,j} / \sum_k w_{i,j}$. The 95 % confidence interval of this estimate is derived from its standard error $x_{\mathrm{SE},j}$ as $x_j \pm 1.96\, x_{\mathrm{SE},j}$. For indicators that are proportions, the weighted mean values and corresponding 95 % confidence intervals are calculated using year-specific weighted logistic regression models of the type $\mathrm{logit}(n_{\mathrm{subgroup},i,j}/n_{\mathrm{total},i,j}) \sim x'_j$, where $n_{*,i,j}$ is the number of individuals in province i in year j and x'_j is the estimated mean indicator on the logit scale. This estimate and its 95 % confidence interval are then back-transformed to the original scale using the inverse logit function.

In the main text, all results are based on weighted survey data. For comparison, the corresponding unweighted results are shown in Sections A9 and A10 of the Appendix.

2.2.7. Standardization of indicators

As a final, optional step, we standardize all univariate indicators in two ways. First, for assessing developments in the fishery population in comparison with other demographic groups, we divide indicators of the fishery population by the corresponding indicators of the other demographic groups. Second, for assessing developments in the fishery population over time across different indicators, we divide indicators of the fishery population by the corresponding initial indicators.

3. Results

3.1. The fishery population is shrinking

The size of the fishery population is showing very similar trends when considered in terms of absolute indicators (Fig. 1a and c) or relative indicators (Figs. 1b and 1d). These indicators are shown based on data from the China Fisheries Yearbook (CFY) and the China Health and Nutrition Survey (CHNS). According to the CFY, China's fishery population as a proportion of China's total population increased from about 1–1.5 % from 1989 to 1996, stayed at around that level until 2013, and has been slowly declining ever since (Fig. 1d, grey bars): as a proportion of China's total population, it has dropped from 1.5 % in 2013 to 1.2 % in 2020 (Fig. 1d, grey bars). China's traditional-fishery population as a proportion of China's total population has been declining in every year since the reporting began in 2003 (Fig. 1d, black bars), while China's population of fishery practitioners as a proportion of China's total population has been more stable (Fig. 1d, purple bars). The CHNS-based indicator of the fishery population (Figs. 1a and 1b, green bars) is closest to the CFY-based population of fishery practitioners (Figs. 1c and 1d, purple bars).

Not only is the relative proportion of China's fishery population shrinking (Figs. 1b and 1d), but even its absolute size is shrinking (Figs. 1a and 1c), despite a growing total population. All CFY-based indicators of absolute size have declined since 2012 (Fig. 1c). While the CHNS-based indicator of the fishery population (Figs. 1a and 1b, green bars) covers only the beginning of these declines, it is showing the same qualitative trend.

3.2. The fishery population is ageing but more slowly than the total population

The age distribution of the fishery population estimated based on the CHNS shows a trend of gradual ageing (Fig. 2). Men and women reporting fishing activity both exhibit this trend (Fig. 2a). The average age of the fishery population was 38 years in 1989, whereas it has risen

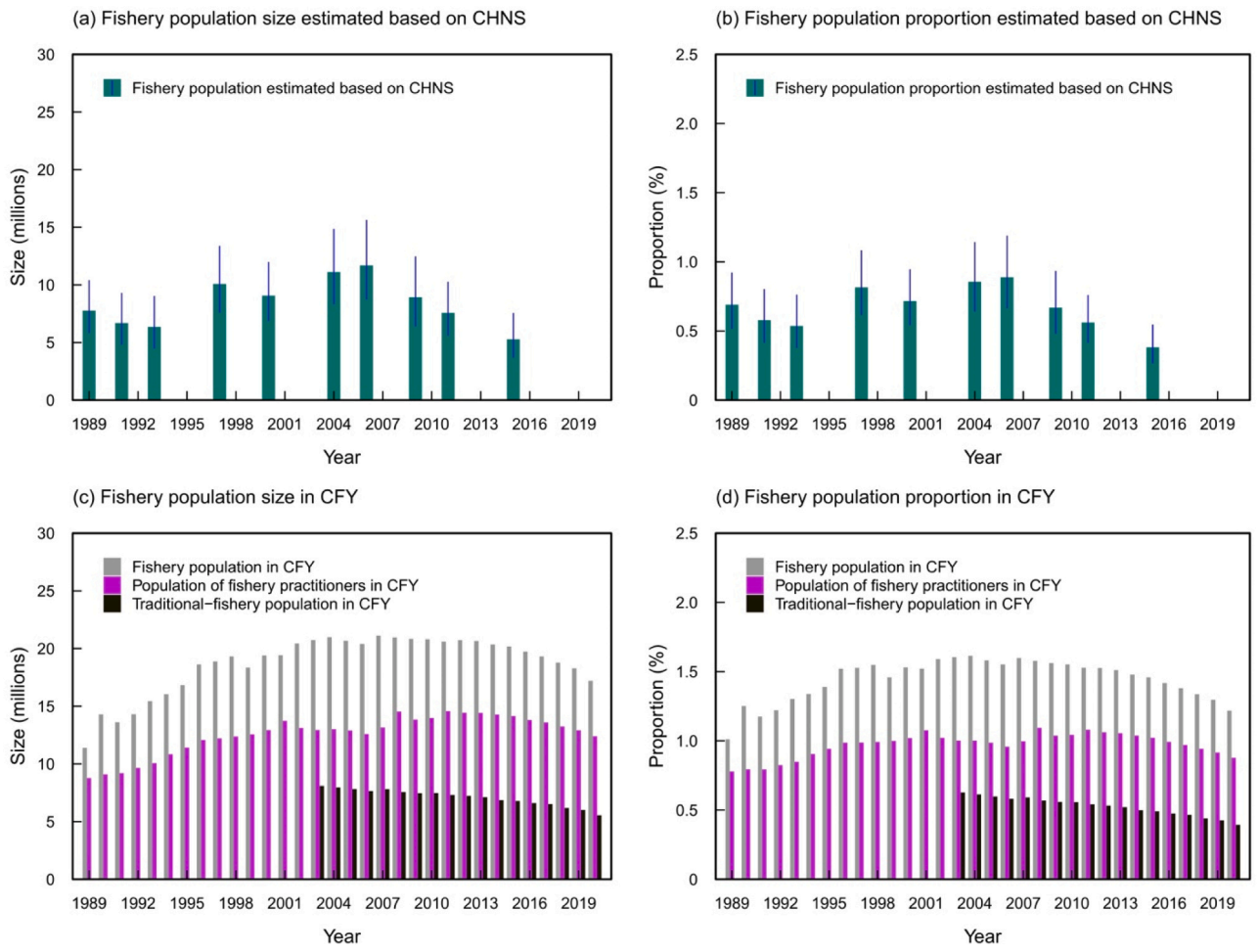

Fig. 1. Development of the size of China's fishery population and of its proportion of China's total population. (a) Size of China's fishery population according to the China Health and Nutrition Survey (CHNS). (b) Size of China's fishery population as a proportion of China's total population according to the CHNS. (c) Size of China's fishery population according to the China Fisheries Yearbook (CFY). (d) Size of China's fishery population as a proportion of China's total population according to the CFY.

to 52 years in 2015 (Fig. 2b). When the total survey population is split into rural and urban segments, the rural population turns out to be slightly older than the urban population, with both segments being consistently and considerably younger than the fishery population (Fig. 2b).

The fishery population is ageing more slowly than the rural and the urban population segments (Fig. 2b). The age gap between the fishery population and the two other segments has narrowed, from 9.1 years at the beginning of the time series to 7.2 years at its end when measured relative to all survey respondents. Indeed, the relative age of the fishery population, defined by the ratio of the mean age of the fishery population to the mean age of the total population, shows a declining trend because the total population has been aging faster than the fishery population (Fig. 6; Table A5). In line with this observation, the proportion of persons aged 65 years or older is smaller in the fishery population than in the total population and started to rise later in the fishery population than in the total population (Fig. 2c).

3.3. The fishery population's education levels are rising

The average durations of education in the fishery population are similar to those of rural residents but lower than those of urban residents and of the total population, consistently over all survey years (Fig. 3a). From 1989–2015, the average education duration of the fishery population has steadily increased, from 5 years to 7 years. Despite this rise, the average education duration of the fishery population has consistently remained below that of urban residents, which by 2015 has been exceeding 9 years. The ratio of the fishery population's average education duration to the total population's average education duration has steadily declined (Fig. 6; Table A6). Thus, the average education duration of the fishery population is not only lower than that of the total population, but their gap is increasing, if only slightly (Fig. 3a).

In the fishery population, primary-school graduation and junior-high-school graduation currently are the two most common levels of educational attainment, as the proportion of workers without any graduation has more than halved during the last 30 years (Fig. 3b). While the educational status of rural residents was similar to those of the fishery population in the first three surveys of 1989–1993, a rising proportion of rural residents subsequently accomplished higher levels of educational attainment, such as technical or vocational graduation and university or college graduation (Fig. 3c) – a development that hardly occurred in the fishery population (Fig. 3b). Fig. 3 also shows that urban residents have consistently been more likely to boast higher levels of educational attainment than rural residents and fishery workers, with the proportion of persons graduating at least from senior high school reaching almost 50 % in the last survey of 2015 (Fig. 3d).

3.4. The fishery population's incomes are growing but are falling behind

Throughout the survey years, the incomes of the fishery population

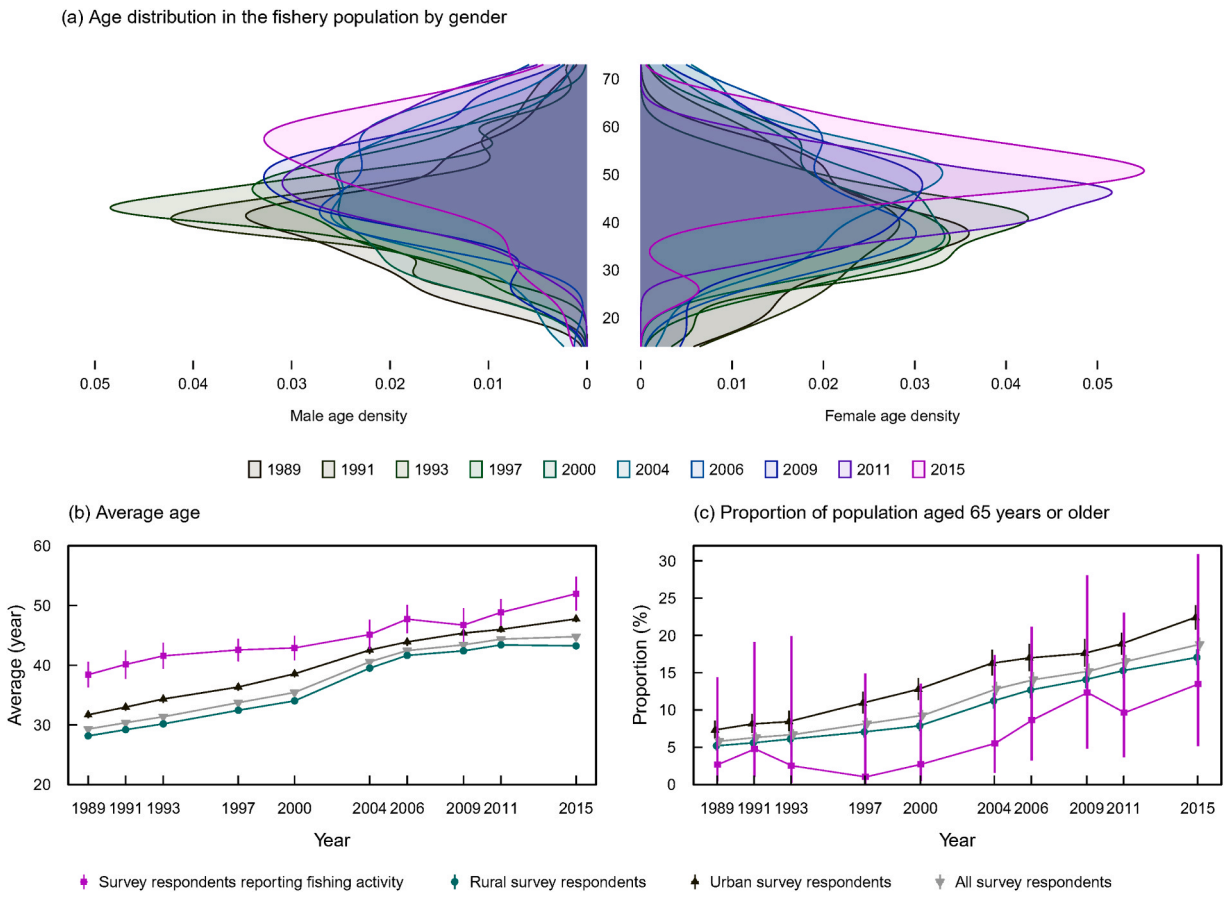

Fig. 2. Age distributions in the fishery population and aging trends in the fishery, rural, urban, and total populations, based on data from the China Health and Nutrition Survey (CHNS). (a) Age distributions in the fishery population by gender. The horizontal axes show the age density, with males on the left-hand side and females on the right-hand side of the vertical axis indicating their age. All age distributions are smoothed using a Gaussian kernel density estimate based on Silverman's rule (Methods). (b) Average ages in the fishery, rural, urban, and total populations. (c) Proportions of the population aged 65 years or older in the fishery, rural, urban, and total populations.

have been rising in real terms, i.e., even after accounting for inflation (Fig. 4). However, the incomes of the fishery population have increased more slowly than the incomes of the rural and urban populations (Fig. 4). Before 1997, the median incomes of the fishery, rural, and urban populations were very similar. In the surveys of 1989 and 1997, the median and average incomes of the fishery population were even distinctly higher than those of the other population segments. From 2000 onward, the median and average incomes of the fishery and rural populations have been falling behind that of the urban population. In the last survey of 2015, the median income of the fishery population is now lagging even that of the rural population. These developments are mirrored by the ratio of the average income of the fishery population to the average income of the total population (Fig. 6; Table A7).

3.5. *The fishery population's occupational mobility is high*

We assess occupational mobility in two ways, in terms of the directions and frequencies of occupational transitions (left column of Fig. 5) and in terms of the durations for which survey respondents are reporting fishing activity (right column of Fig. 5).

The three panels in the left column of Fig. 5 describe the transitions into and out of fishing occupations across survey years. Fig. 5a shows the proportions of respondents reporting fishing activity for three different timeframes. For the single-survey timeframe, this is simply the proportion of survey respondents reporting fishing activity in the latest survey. For the two-survey and three-survey timeframes, the value is the proportion of respondents reporting fishing activity in at least one of the latest two or three surveys. Since the 2006 survey, the proportion of fishery participants has declined for all three timeframes, in line with the results shown in Fig. 1.

At the fine scale of the two-survey and three-survey timeframes, the sample sizes are low, but some patterns are nevertheless evident. The analysis of two consecutive surveys in Fig. 5b shows that only about 20 % of respondents have stayed in the fishing sector from one survey to the next. In contrast, higher proportions of survey respondents, 30 % and 27 % on average, have either left or joined the fishing sector, respectively. We also observe that more individuals have left than joined the fishing industry after the 2006 survey, which again is consistent with the results shown in Fig. 1.

The analysis of three consecutive surveys in Fig. 5c shows that the proportions of survey respondents classified as "Stayed", "Left", and "Joined" exhibit similar trends using the three-survey timeframe and the two-survey timeframe. In particular, more individuals have left than joined the fishing industry since the 2004 survey, again in line with the results shown in Fig. 1. The absolute frequencies of the "Stayed", "Left", and "Joined" transitions are smaller using the three-survey timeframe than using the two-survey timeframe: this is because two additional, more complex types of occupational mobility become discernable only when using the three-survey timeframe. These correspond, respectively, to survey respondents classified as "Joined-and-left" and "Left-and-joined", with the corresponding occupational transitions having occurred at proportions of 18 % and 5 % on average, respectively. This shows that about one quarter of survey respondents have changed their fishery occupation back and forth over the course of three consecutive

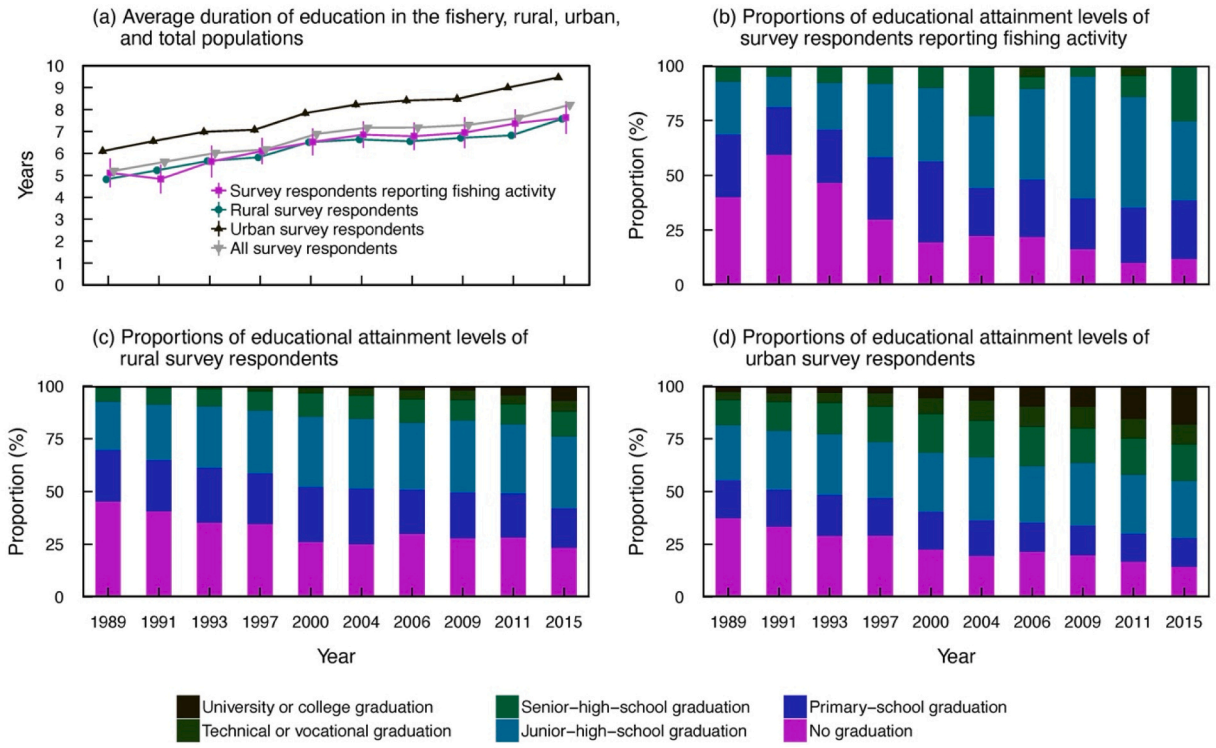

Fig. 3. Educational status of the fishery, rural, and urban populations, based on data from the China Health and Nutrition Survey (CHNS). (a) Average duration of education (with 95 % confidence intervals) in the fishery, rural, urban, and total populations. (b), (c), (d) Proportions of educational attainment levels in the fishery, rural, and urban populations, respectively. The corresponding figure and underlying data without weighting are shown in Sections A9 and A10 of the Appendix.

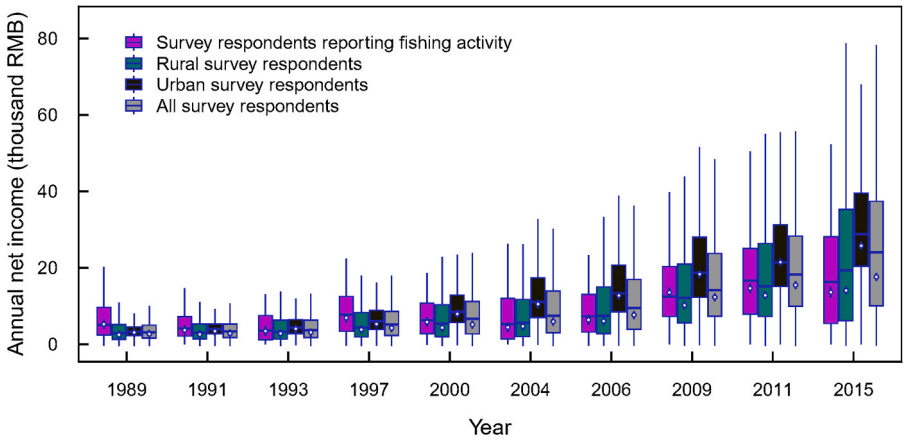

Fig. 4. Net annual incomes of the rural, urban, fishery, and total populations, based on data from the China Health and Nutrition Survey (CHNS). Distributions of incomes are shown in Chinese yuan (RMB) inflated to the 2015 level. The upper and lower edges of the boxes indicate the quartiles, the horizontal lines in the middle of the boxes indicate the medians, and the vertical lines attached to the boxes indicate the ranges between the 1st and 99th percentiles. The geometric mean income (with 95 % confidence intervals) is indicated by white circles.

surveys. It further reveals that individuals have been five times more likely to join the fishing sector for continual durations captured by a single survey than they conversely have been to leave it for a single survey, which again reflects the high occupational mobility associated with the fishing sector by indicating that short periods of joining are considerably more common than short periods of leaving.

The ratio between the proportion of "Left" transitions in the fishery population and the proportion of "Left" transitions in the total population exceeds 1 in all survey years (Fig. 6; Table A8). This means that the fishery population experiences a higher outward occupational mobility than the total population. In other words, compared with people working in other sectors, more employees in the fishing industry have chosen to alter their occupational sector.

The three panels in the right column of Fig. 5 show durations of fishing-occupation periods. Fig. 5d shows continual durations (from a respondent's joining to a respondent's next leaving of reporting the considered occupation), Fig. 5e shows summed durations (of a respondent's continual durations of reporting the considered occupation), and Fig. 5f shows total durations (from the beginning of a respondent's first to the end of a respondent's last continual durations of reporting the considered occupation). The frequency distributions of the three measures of occupation periods are shown together with their means and medians.

The panels also show the corresponding frequency distributions, as

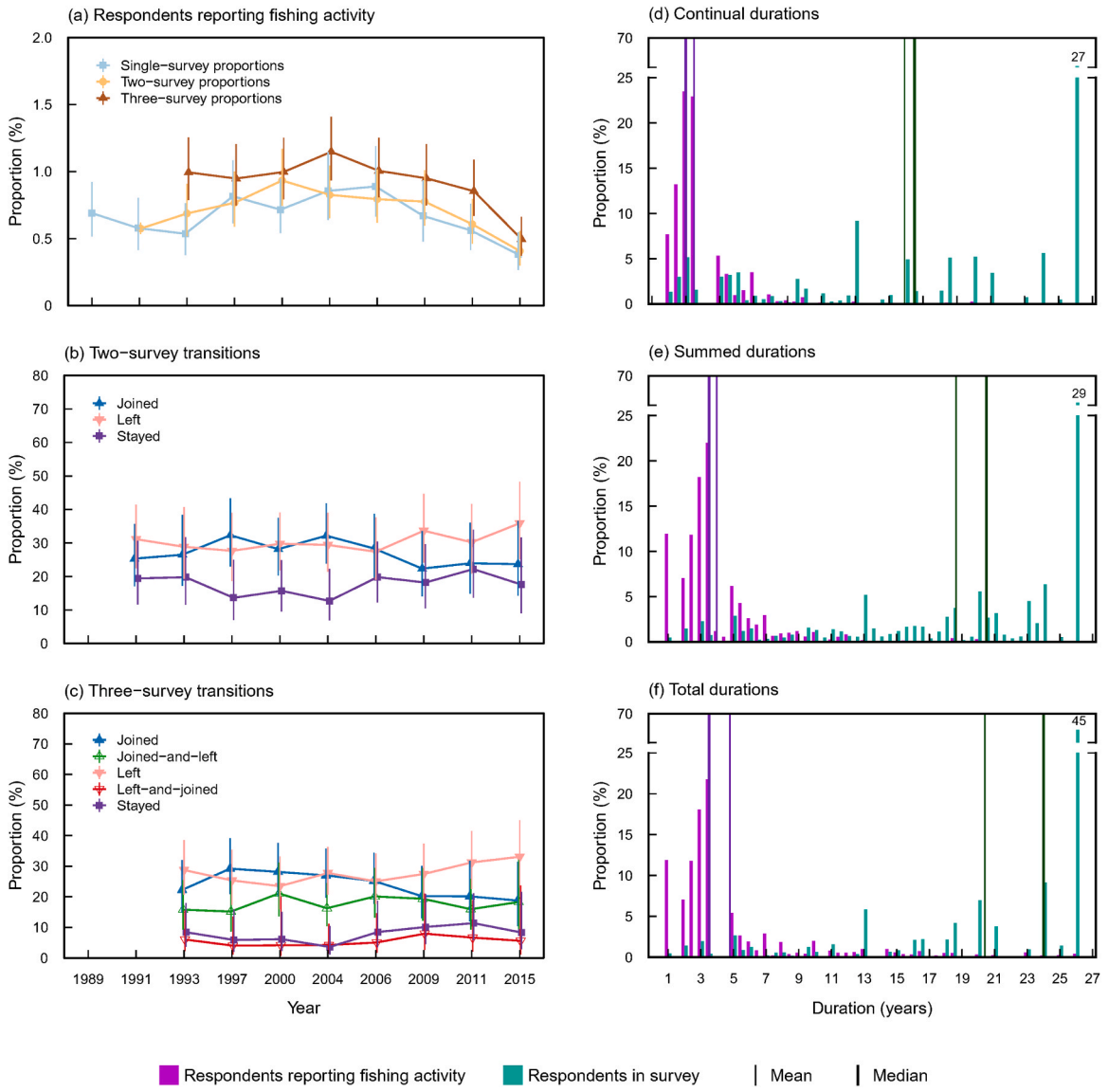

Fig. 5. Directions and frequencies of occupational transitions (left column) and durations of fishery occupation (right column), based on data from the China Health and Nutrition Survey (CHNS). (a) Proportions of respondents reporting fishing activity among all survey respondents, using single-survey, two-survey, and three-survey timeframes. (b) Occupational transitions in the fishery population using the two-survey timeframe. (c) Occupational transitions in the fishery population using the three-survey timeframe. The three panels in the right column show the frequency distributions of, across the rows, three alternative quantitative measures of the duration of periods in the fishery and survey populations. (d) Frequency distributions of continual durations of fishery occupation and CHNS participation (calculated from a respondent's joining to the respondent's next leaving). (e) Frequency distributions of summed durations of fishery occupation and CHNS participation (calculated by adding all of a respondent's continual durations). (f) Frequency distributions of total durations of fishery occupation and CHNS participation (calculated from the beginning of a respondent's first to the end of the respondent's last continual durations). The vertical bars in panels a–c show 95 % confidence intervals. The median values in panels d–f are the real-valued durations at which the piecewise uniform probability density function given by the shown histograms accumulates to 50 % across histogram bars (Simpson and Kafka, 1952; see also Section A7 of the Appendix and Fig. A2 in the Appendix). The corresponding figure and underlying data without weighting are shown in Sections A9 and A10 of the Appendix.

well as the means and medians, of the durations for which fishery respondents have been participating in the survey. For all three measures of occupation periods, the frequency distributions of survey participation peak at the longest possible duration of 26 years, and the means and medians of the durations of survey participation are 4–5 times longer than the means and medians of the durations of reported fishing activity.

Fig. 5d shows that continual durations of 1–5 years are most common for the reporting of fishing activity, with a median of 3.0 years and a mean of 3.5 years. This means that joining the fishing sector for periods as short as three years on average is the pattern of occupational mobility dominating the fishery population.

Figs. 5e and 5f show that the frequency distributions of summed and total durations are very similar to that of continual durations. The corresponding medians and means are also very similar, at 3.5 years and 4.1 years for summed durations and 3.5 years and 4.8 years for total durations, respectively. This means that very few survey respondents have returned to fishing activity after having left the fishing sector. This is consistent with the results for the "Left-and-joined" transition shown in Fig. 5c based on the three-survey timeframe.

We strengthen this result by extending our analysis of the rejoining of fishing activity from the three-survey timeframe to all surveys. We find that 90 % of CHNS respondents from 1989 to 2015 have reported fishing activity for only a single continual duration, while as few as 9 % and 1 %, respectively, have reported fishing activity for two or three

continual durations. In summary, once workers leave the fishing industry, they are mostly gone forever.

3.6. Summary of key results

For an integrative perspective on the trends in the socio-economic characteristics of China's fishery population over the past three decades, all indicators presented in Sections 3.1–3.5 are shown together in Fig. 6. To maximize the utility of this synopsis, we show each indicator in absolute and relative terms: for the fishery population (Fig. 6a) and for the ratio between the fishery population and the total population (Fig. 6b). To facilitate comparison among all indicators and their trends, we standardize each indicator with respect to the value in its first year. Together, the ten indicator curves thus defined highlight not only how the fishery population's socio-economic characteristics have changed over time but also how these changes compare to the corresponding changes in the total population:

- *Size* – *Section 3.1* . The estimated size of the fishery population was slowly increasing until 2006 and has rapidly declined thereafter (Fig. 6a, pink curve). In contrast to the absolute indicator, the ratio between the size of the fishery population and the size of the total population was almost constant until 2006, while, in agreement with the absolute indicator, this ratio has rapidly declined thereafter (Fig. 6b, pink curve). Thus, after 2006, the fishery population has been shrinking both in absolute and in relative terms.
- *Age* – *Section 3.2* . The mean age of the fishery population shows a moderate but steady positive trend, which means that the fishery population has been, and currently still is, ageing (Fig. 6a, purple curve). Meanwhile, the ratio between the mean age of the fishery population and the mean age of the total population has been decreasing (Fig. 6b, purple curve). Thus, while the fishery population has been aging, the total population has been aging faster.
- *Education* – *Section 3.3* . The mean duration of education in the fishery population has steadily increased since 1991 (Fig. 6a, yellow curve). However, when comparing the mean duration of education in the fishery population with that in the total population, we observe the opposite trend: the ratio of the fishery population's mean duration of education and the total population's mean duration of education is showing a moderately negative trend (Fig. 6b, yellow curve). In particular, we find that the mean duration of education of the fishery population relative to that of the total population has dropped by about 10 % over the last three decades.
- *Income* – *Section 3.4* . The average income in the fishery population was about four times higher in 2015 than the corresponding inflation-adjusted income in 1989. This overall increase is distinctly biphasic: the inflation-adjusted average income remained essentially unchanged until 2004 and since then has rapidly increased (Fig. 6a, blue curve; notice the comparatively compressed scale of the right-hand vertical axis used for this, and only this, indicator). Our comparison with the average income in the total population demonstrates that during the period of no income increases in the fishery population until 2004 the fishery incomes were seriously and increasingly lagging behind the rise in nationwide incomes, whereas during the period of rising incomes in the fishery population after 2004 the fishery incomes have matched, in relative terms, the rise in rise in nationwide incomes (Fig. 6b, blue curve). In other words, the relative economic status of the fishery population has stabilized but, because of the long lag until 2004, at a relatively poor level of only about 45 % of the relative economic status it had in 1989.
- *Mobility* – *Section 3.5* . The proportion of 'Left' transitions among 'Left' and 'Stayed' transitions in the fishery population using the two-survey timeframe shows a fluctuating pattern with a slightly increasing overall trend (Fig. 6a, black curve). The ratio between this proportion of 'Left' transitions in the fishery population and the corresponding proportion of 'Left' transitions in the total population shows similar variability but with a slightly decreasing overall trend (Fig. 6b, black curve). Compared with the total population, workers in the fishery population have been twice as likely to leave their occupation (Table A8).

4. Discussion

Since the beginning of China's "Reform and Opening-up" program in 1979, China's population, economy, and society have undergone unprecedented changes. China has experienced a rapidly ageing population (Mao et al., 2020), higher-education expansion (Liu and Wan, 2019), income growth (Luo et al., 2020), and massive internal population migration (Su et al., 2018). The present study uses nationwide, individual-level, longitudinal survey data to analyze changes in China's fishery population that have occurred during the period of wider societal change. We find that the size of China's fishery population has been shrinking between the surveys of 2006 and 2015 (Section 3.1). This finding is corroborated by also showing that, during this period, the numbers of individuals leaving the fishery sector have exceeded those of joining it (Section 3.5). We also find that occupational mobility is very high in the fishery sector in general and that most fishers stay in the fishing industry only for short durations (Section 3.5). At the same time, China's fishery population has aged (Section 3.2), become more educated (Section 3.3), and gotten wealthier (Section 3.4). While these trends are qualitatively akin to those in China's total population, they are weaker: while not aging and becoming more educated quite as much as the total population, the relative socio-economic status of the fishery population has fallen (Section 3.6). The latter trend is very pronounced,

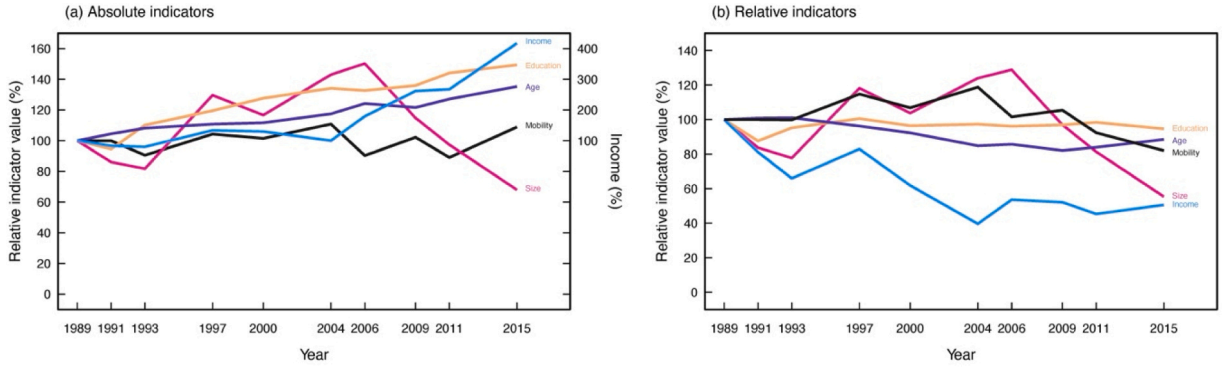

Fig. 6. Time series of key indicators of the fishery population's size (magenta), age (purple), education (orange), income (blue), and occupational mobility (black). (a) Indicators directly describe fishery population. (b) Indicators describe the fishery population relative to China's total population. 'Mobility' refers to the proportion of 'Left' transitions among 'Left' and 'Stayed' transitions in the fishery population using the two-survey timeframe. All time series are standardized with respect to their starting values (first year = 100 %).

having resulted in a precipitous drop in relative fishery incomes by nearly 60 % during 1989–2015.

4.1. Size and mobility structure of fishery population

The size of China's fishery population and its share of the total population have both decreased during 1989–2015. Two factors may have contributed to this decline: occupational mobility and fishery policies. Consistent with the decline of the fishery population, we have found that a higher proportion of respondents left the fishery population than joined it. Our results also demonstrate the highly temporary nature of employment in the fishery sector. The durations between workers joining and leaving fishery occupations are usually short, with workers typically appearing in the subset of fishery respondents only for one survey before disappearing again. The elevated occupational mobility in China's fishery population could be explained by China's high proportion of small-scale fisheries, which are usually hiring numerous temporary workers (Lindkvist et al., 2008; Su et al., 2020). While we could find only limited information on the non-fishery occupations of workers who moved in and out of the fishery sector, it has been suggested that workers who joined the fishery sector had preceding occupations classified as inland farmers (Lindkvist et al., 2008). It has also been shown that engaging in part-time jobs is a common pathway for fishers to initiate and complete a job transfer (Zheng et al., 2021).

Another factor that could potentially be contributing to the decline in China's fishery population are China's fishery policies. There are two key policy aspects to consider. First, while the huge size of the fishery population implies many valuable employment opportunities, which can be interpreted as a positive outcome of China's fishery production system (Szuwalski et al., 2020), it also serves as a driver of overcapacity in the fishing industry (Yu and Yu, 2008). Second, for China's fishers working in marine capture fisheries, the bilateral fisheries agreements China has signed with Japan, South Korea, and Vietnam have led to a loss of traditional fishing grounds (European Parliament, Directorate General for Internal Policies of the Union, 2012; Su et al., 2020). These two aspects motivate policies designed to reduce the fishing industry's labor surplus and to compensate fishers for losses caused by the bilateral fisheries agreements.

Moving fishers to other industries, through actions like subsidies for retraining and redeployment, has been a policy for the past two decades (He, 2015; Cao et al., 2017; Huang and He, 2019). This process has started with a program called "Fishermen Transfer and Fishery Transition Program" ("渔民转产转业项目", translated according to Cao et al., 2017) published in 2003 and continued with other policies like the vessel buyback program ("渔船报废计划", translated as "Fishing Vessel Scrapping Program" by Yu and Yu, 2008) launched with an 8-year plan (2003–2010), which explicitly aimed at moving 4 % of fishers to other jobs by 2010 (Yu and Yu, 2008). It has been suggested, however, that these policies have met with limited success (Cao et al., 2017) and have not played a conspicuous role in promoting occupational mobility out of the fishery sector (Zheng et al., 2021). While the vessel buyback program has proven to have a positive effect on increasing the exit rate of old and small vessels in one province (Wang et al., 2023), it has had an unclear impact on helping the transition of fisher's occupations. An important reason might be that some traditional fishers strongly rely on their traditional way of life, making it especially difficult to relocate them (Fabinyi, 2012; Shen and Heino, 2014). It is also possible that compensations offered for losses caused by the bilateral fisheries agreements have to some extent counteracted incentives that would otherwise have caused fishers to leave the fishery sector. Accordingly, fishery policies aimed at reducing the fishery population have not been as effective as expected. This is suggesting, in turn, that fishery policies are not among the most important factors impacting the size of China's fishery population.

It is against this backdrop that Zheng et al. (2021) have found other factors more important in impacting the size of China's fishery population to include technological progress, continued urbanization, and the income gap between rural residents and marine fishers. The application of new technologies has allowed the substitution of technology and capital for labor, reducing the labor intensity of Chinese marine fisheries (Sun and Li, 2018). Potential job opportunities in other sectors also affect the realized employment in the fishing industry, as seen in some underdeveloped countries and regions in Asia (Teh and Sumaila, 2013). In addition, social capital (community cohesion and close relationships), economic capital (subsidies) and institutional support, education and family size are all factors that impact the fishers' employment choices and income structure (Eskander et al., 2018; Malakar et al., 2018; Zhao and Jia, 2020).

4.2. Age structure of fishery population

We have shown that China's fishery population not only has a higher average age than China's total population but is also undergoing further ageing – two observations that are in agreement with earlier studies (Tong et al., 2013b; Huang, 2014). Similar trends are also taking place in other regions, described as the "graying of the fleet" in the United States (Cramer et al., 2018; Donkersloot and Carothers, 2016; Haugen et al., 2021). The documented aging trend in China's fishery population could be caused by multiple factors: a reduced recruitment of young workers to the fishing sector, a higher tendency of young workers to leave the fishing sector, and/or longer career durations within the fishing sector. In Alaska, recruitment was recognized as an important driver of ageing, reflecting factors such as the high cost to enter the fishery (Cramer et al., 2018). Personal interviews with fishers indicate that reduced recruitment certainly plays an important role also in China, as most members of the young generation in fisheries families have no willingness to do fisheries work (Y. Huang, unpublished data). Since these younger workers are on average more educated than their parents, they can more easily find occupations outside of the fishing industry. Meanwhile, the work on fishing vessels requires professional skills and specialized experience, which currently are mostly provided by the senior fishers. Since such an over-reliance on senior fishers is bound to cause problems in the future, it is important that, in comparison to the total population, the ageing of China's fishery population is slower: if continued, this relative trend will bring the age distribution of China's fishery population closer to the national average.

4.3. Education structure of fishery population

The education level of fishers, though rising, remains below the national average. Lower levels of education may make it difficult for fishers to leave the fishery sector and move on to other jobs (Su et al., 2020). Supporting the acquisition of the professional skills fishers need for working in agriculture or other sectors facilitates their occupational mobility (Clark et al., 2005; Gallizioli, 2014). Accordingly, fisheries policies encouraging fishers to work in other sectors have been supported by the establishment of a retraining system for teaching the needed professional skills (He, 2015; Su et al., 2020; Szuwalski et al., 2020). Such retraining has been recognized as crucial to solving the employment problem of displaced fishers (White, 2003). Unsurprisingly, fishers with already higher levels of education are better able to receive such retraining and benefit from it. Conversely, a persistent problem faced by local fisheries managers implementing retraining programs is the low education level of a large fraction of the workers to be retrained (Teh et al., 2017).

4.4. Income of fishery population

The rising trend of the fishers' income has occurred in parallel with the development of China's economy. In the early part of the survey period, the fishery population was a relatively well-off segment of the society. From the year 2000 onward, however, the average income of

China's fishery population has been falling behind that of people in urban households; in the currently latest available survey of 2015, the median income was even lower than that of people in rural households. This trend is consistent with our former research based on interview data (Tong and Huang, 2013). Statistics show that the income of fishers mainly accrues from their family businesses (Jiang et al., 2012; Yue et al., 2017). Macroeconomic growth, the steadily increasing prices of aquatic products, the expansion of the import and export trade of aquatic products, and some policies aiming at poverty alleviation have influenced the incomes of fishers positively (Jiang et al., 2012). At the same time, natural disasters, higher costs of fishing, and a downward adjustment of policies determining fuel subsidies have influenced the incomes of fishers negatively (Yue et al., 2017). Also a decline in the production of marine capture fishing and the increase in aquaculture production in some coastal provinces from 2000 onwards have influenced the incomes of fishers negatively (Ministry of Agriculture Bureau of Fisheries, 2022). Experience from elsewhere suggests that such negative drivers could have been offset by technology-driven productivity growth, but perhaps not without reducing employment (Hannesson, 2007).

4.5. Limitations and future research

This study has used data collected through the China Health and Nutrition Survey (CHNS) to survey China's general population. This survey is unique in combining a broad geographic and temporal coverage with questions relating to a diverse range of socio-economic indicators. At the same time, the survey has not been specifically designed to focus on the fishery industry or the fishery population. Consequently, the sample sizes of CHNS respondents from the fishery population—a comparatively small segment of the general population (Fig. 1b)—are not large. It is also possible that the CHNS has not managed to sample this segment of the general population representatively. For example, only about half of the Chinese provinces are covered by the CHNS. At present, there are no data to evaluate whether this subset of provinces is representative, but we are not aware of any obvious concerns of this kind, and we have shown that the results we have obtained are not sensitive to whether provincial-level statistical weighting is applied. Moreover, the CHNS does not differentiate between individuals involved in capture fishing or aquaculture, or between individuals involved in marine fisheries or freshwater fisheries, all of which are important in China. Note also that the CHNS respondents we have attributed to the fishery population include individuals involved in "collective fishery". This type of fishing is analogous to collective farming and includes various types of "fishery production in which multiple fishers run their holdings as a joint enterprise" (Yang and Yan, 2008). Therefore, the subset of fishery respondents includes individuals who were secondarily or indirectly involved in, or supported by, fishing activities. Yet even more inclusive definitions of fishery population could be conceived by including, for example, the population involved in fishery-related industries such as those manufacturing fishing vessels, fishing gear, and corresponding machinery (Speir et al., 2020).

4.6. Outlook

During the last decade, the objective of reducing overcapacity has been an important element in policies aimed at improving the sustainability of the fisheries sector in China. This has involved reducing fuel subsidies and vessel buyback programs (Wang et al., 2023), together with fisher-transfer programs (Huang and He, 2019), measures that inevitably affect the lives and livelihoods of the fishery population. A few scientific studies have come up with concrete suggestions on how to address these human dimensions of fishery issues in China, such as investing in new job opportunities for fishing communities (Cao et al., 2017), diverting fuel subsidies to refocus on the retraining of fishers (Yang et al., 2017), and enabling fishers to participate in fisheries management (Yu and Yu, 2008). While it has been proposed that the success of such actions could be enhanced by implementing them through the self-governance of fishers based on local organizations and right-based management (Yu, 1991; Wang and Zhan, 1992; Liu et al., 2020), none of the aforementioned studies have provided further analyses showing that such actions are workable or scientific advice on how to implement them in practice. Our research indicates that the efficient implementation of fisher-transfer programs is likely severely hindered by the instability of employment in China's fishery population. Accordingly, this instability needs to be analyzed and accounted for as a minimal prerequisite for improving the success of such programs in the future.

We hope that our analyses of the characteristics and structure of China's fishery population can help decision-makers better to understand this segment of the general population, as a necessary first step towards finding workable solutions to the complex challenges faced by China's fishery industry and fishery population (Jentoft, 1997; Liu, 2006; Han et al., 2007; Lin, 2010). We believe that decision-makers in fishery management and researchers in fishery science can benefit from an enhanced analytical focus on, and resultant quantitative understanding of, the characteristics and structure of the fishery population. How to realize the sustainable development of the fishery industry under the premise of ensuring the livelihoods of the fishery population is the key question managers, scientists, and fishers need to solve together.

CRediT authorship contribution statement

Huang Yi: Writing – review & editing, Writing – original draft, Visualization, Validation, Supervision, Software, Resources, Project administration, Methodology, Investigation, Funding acquisition, Formal analysis, Data curation, Conceptualization. **Heino Mikko Petteri:** Writing – review & editing, Visualization, Validation, Supervision, Software, Resources, Project administration, Methodology, Investigation, Funding acquisition, Formal analysis, Conceptualization. **Dieckmann Ulf:** Writing – review & editing, Visualization, Validation, Supervision, Resources, Project administration, Methodology, Investigation, Funding acquisition, Formal analysis, Conceptualization.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Acknowledgements

We thank two reviewers and the editor for their constructive feedback. The authors gratefully acknowledge funding from the International Institute for Applied Systems Analysis (IIASA) and the National Member Organizations that support the institute. In particular, this work was supported by IIASA's Young Scientists Summer Program (YSSP), with YH's participation in the YSSP funded by the National Natural Science Foundation of China (NSFC). The authors gratefully acknowledge additional financial support by the China Scholarship Council (grant number CSC201806310026) and the Norwegian Research Council (grant number 288037). The authors furthermore acknowledge funding this research has received from the European Union's Horizon 2020 research and innovation programme under grant agreement No 820989 (project COMFORT, Our common future ocean in the Earth system –quantifying coupled cycles of carbon, oxygen, and nutrients for determining and achieving safe operating spaces with respect to tipping points) – the work reflects only the authors' view; the European Commission and their executive agency are not responsible for any use that may be made of the information the work contains. At the request of the researchers having conducted the China Health and Nutrition Survey

(CHNS), we also include their acknowledgements: "This research uses data from the CHNS. The CHNS researchers thank the National Institute for Nutrition and Health, the China Center for Disease Control and Prevention, the Carolina Population Center (P2C HD050924, T32 HD007168), the University of North Carolina at Chapel Hill, the National Institutes of Health (NIH; R01-HD30880, DK056350, R24-HD050924, and R01-HD38700), and the NIH Fogarty International Center (D43-TW009077, D43-TW007709) for financial support for the CHNS data collection and analysis from 1989 to 2015 and future surveys, as well as the China-Japan Friendship Hospital and the Ministry of Health for financial support for the CHNS 2009, the Chinese National Human Genome Center at Shanghai for financial support for the CHNS since 2009, and the Beijing Municipal Center for Disease Prevention and Control for financial support for the CHNS since 2011."

Appendix

A1. Identification and selection of data sources

To identify the most suitable data sources for our study, with extensive coverage across both space and time, we scrutinized information provided by several academic institutions that not only conduct social surveys themselves but also collate metadata on social surveys conducted by others. The organizations we have checked are as follows:

- Survey and Data Center of the Chinese Academy of Social Sciences (中国社科院调查与数据信息中心)
- National Survey Research Center at Renmin University of China (中国人民大学中国调查与数据中心)
- Institute of Social Science Survey of Peking University (北大中国社会科学调查中心)
- Tsinghua China Data Center (清华大学中国经济社会数据中心)
- Center for Social Survey of Sun Yat-sen University中山大学社会科学调查中心)
- Shanghai Social Survey and Research Center (上海社会科学调查中心)
- Fudan Institute of Social Research (复旦大学社会科学数据研究中心)

From the organizations listed above, we could identify a total of seven potentially relevant surveys (Table A1). All of these are long-term, nationwide surveys containing socio-economic indicators. We then checked the questions and response options of each survey to determine whether the terms 'fishery' (渔业), 'fishing' (渔业,捕鱼,捕捞), or 'fish' (as a noun: 鱼; as a verb: 捕鱼,钓鱼) were mentioned. Compared with the six other surveys, the China Health and Nutrition Survey (CHNS) is providing more information related to fishery and fishing over a long period of time, with many participants having been followed continuously. This feature enables our analysis of occupational mobility. The questionnaires of all considered surveys include several topics addressed using a hierarchical structure, with a leading first-level question and several subsequent second-level questions for each topic. Compared with the six other surveys, the CHNS contains the most second-level questions related to fishery. Considering these two key advantages of the CHNS has compelled us to select the CHNS for our analysis.

Table A1
Seven potentially relevant, long-term, nationwide surveys

Survey name	Survey name in Chinese	Survey years	Coverage and sample size	Survey type	Number of questions (in first and second level[#]) mentioning 'fishery', 'fishing', or 'fish'
China Family Panel Studies (CFPS)	中国家庭追踪调查	2008 and 2009 (pilot study) 2010 (baseline survey) 2011 (maintain baseline sample) 2012, 2014, 2016, 2018	25 provinces* , 14,960 households, 42,590 individuals	Longitudinal survey	1 in first level and 4 in second level in 2010, 2011 surveys; 1 in first level in 2012 and 2014 surveys
Chinese General Social Survey (CGSS)	中国综合社会调查	2003, 2004, 2005, 2006, 2008, 2010, 2011, 2012, 2013, 2015	32 provinces* and ca. 11,000 individuals in every survey year	Cross-sectional survey	0
China Health and Retirement Longitudinal Survey (CHARLS)	中国健康与养老追踪调查	2008 (pilot study) 2011 (baseline survey) 2013, 2015, 2018	30 provinces* , 12,400 households, 17,587 individuals	Longitudinal survey	0
Chinese Household Income Project (CHIP)	城乡居民收入分配与生活状况调查	1988, 1995, 1999, 2002, 2007, 2008, 2013	In 2013, 15 provinces* , 18,948 households, 64,777 individuals	Cross-sectional survey	1 in first level and 1 in second level in 1998 survey; 1 in first level in 1995 and 2002 surveys
Chinese Social Survey (CSS)	中国社会状况综合调查	2006, 2008, 2011, 2013, 2015, 2017	31 provinces* and ca. 7000–10,000 households in every survey year	Cross-sectional survey	0
China Labor-force Dynamic Survey (CLDS)	中国劳动力动态调查	2011 (pilot study) 2012 (baseline survey) 2014, 2016	29 provinces* , 14,226 households, 21,086 individuals	Rotating-sample survey	1 in first level and 2 in second level in 2011 survey; 3 in second level in 2012 survey 1 in first level and 3 in second level in 2014 survey
China Health and Nutrition Survey (CHNS)	中国营养与健康调查	1989 (baseline survey) 1991, 1993, 1997, 2000, 2004, 2006, 2009, 2011, 2015	8–12 provinces* , 11,130 households, 42,829 individuals	Longitudinal survey	2 in first level and 13 in second level in 1989 and 1991 surveys; 2 in first level and 18 in second level in 1993 survey; 2 in first level and 17 in second level in 1997 and 2000 surveys; 2 in first level and 16 in second level in

(*continued on next page*)

Table A1 (*continued*)

Survey name	Survey name in Chinese	Survey years	Coverage and sample size	Survey type	Number of questions (in first and second level[#]) mentioning 'fishery', 'fishing', or 'fish'
					2004 and 2006 surveys; 2 in first level and 15 in second level in 2009, 2011, and 2015 surveys

*The term 'province' here covers all provincial-level administrative units: provinces, provincial-level municipalities, and autonomous regions.
[#]When questionnaires are designed using a hierarchical structure, a topic may be opened with a leading first-level question followed by several subsequent second-level questions. This usually shows in the corresponding answer guide by the instruction "if no, skip to the next topic" for the first-level question, which means that only if the participants answer "yes" to the first-level question they will be asked the second-level questions.

A2. Description of the China Health and Nutrition Survey (CHNS)

A detailed description of the China Health and Nutrition Survey (CHNS) is provided on the project's website (CHNS Project, 2018c). Here we describe the key details that are important for our present study.

The CHNS Project has used a multistage, random cluster process to draw the sample. The sampling design is described as follows (CHNS Project, 2018b; Popkin et al., 2010; Zhang et al., 2014):

(1) In each surveyed province, two cities and four counties were randomly selected: one higher-income city, one lower-income city, one higher-income county, two middle-income counties, and one lower-income county. In most provinces, the provincial capital cities were selected as the higher-income cities. In two provinces, the provincial capital cities were not selected, with other higher-income cities being selected instead.

(2) In each surveyed city, four communities were randomly selected: two urban neighborhoods and two suburban neighborhoods. In each surveyed county, four communities were randomly selected: one community from a township and three rural villages.

(3) In each surveyed community, twenty households were randomly selected. All household members were interviewed.

To maintain their longitudinal survey, the CHNS Project needed to follow the same individuals over several survey years. Naturally, it is unavoidable that some individuals quit the survey and need to be replaced by new ones. We summarize the total sample sizes and respondent retention for the different survey years in Table A2.

Table A2
Total sample sizes and respondent retention of the China Health and Nutrition Survey (CHNS). The top row shows the total sample size in each survey year. The following rows show the retention of individuals in subsequent surveys; individual survey cohorts can be followed vertically. The last two rows show the total numbers of individuals leaving and joining the survey

Year		1989	1991	1993	1997	2000	2004	2006	2009	2011	2015
Respondents		15,907	14,797	13,895	14,441	15,831	12,308	11,860	12,178	15,725	16,622
Respondents remaining in subsequent surveys	**1991**	14,018	–	–	–	–	–	–	–	–	–
	1993	12,739	13,044	–	–	–	–	–	–	–	–
	1997	9300	9518	9933	–	–	–	–	–	–	–
	2000	9352	9494	9710	12,127	–	–	–	–	–	–
	2004	5872	5984	6172	7923	10,078	–	–	–	–	–
	2006	5529	5533	5602	7046	8756	9322	–	–	–	–
	2009	5027	4979	5017	6338	7708	7802	8583	–	–	–
	2011	4423	4373	4410	5432	6594	6794	7338	9235	–	–
	2015	4258	4233	4284	5032	6067	5919	6238	7395	10,810	–
Respondents dropped out		–	1889	1753	3962	2314	5753	2986	3277	2943	4915
Respondents added		–	779	851	4508	3704	2230	2538	3595	6490	5812

The survey was designed in three main components based on the attributes of respondents at three hierarchical levels: individual respondents, their households, and their communities. The corresponding survey components are known as the individual survey, the household survey, and the community survey. Each of these survey components is structured into different parts. In each part, there are topics including several questions. The datasets from the survey follow this same structure. Figure A1 illustrates the structure and content of the survey and the corresponding dataset. The main fishery-specific dataset we used in the present study is derived from Topic 8 in Part C of the individual survey (underlined in Figure A1). Indicators not specific to fishing, such as age and income, are obtained from other parts of the survey.

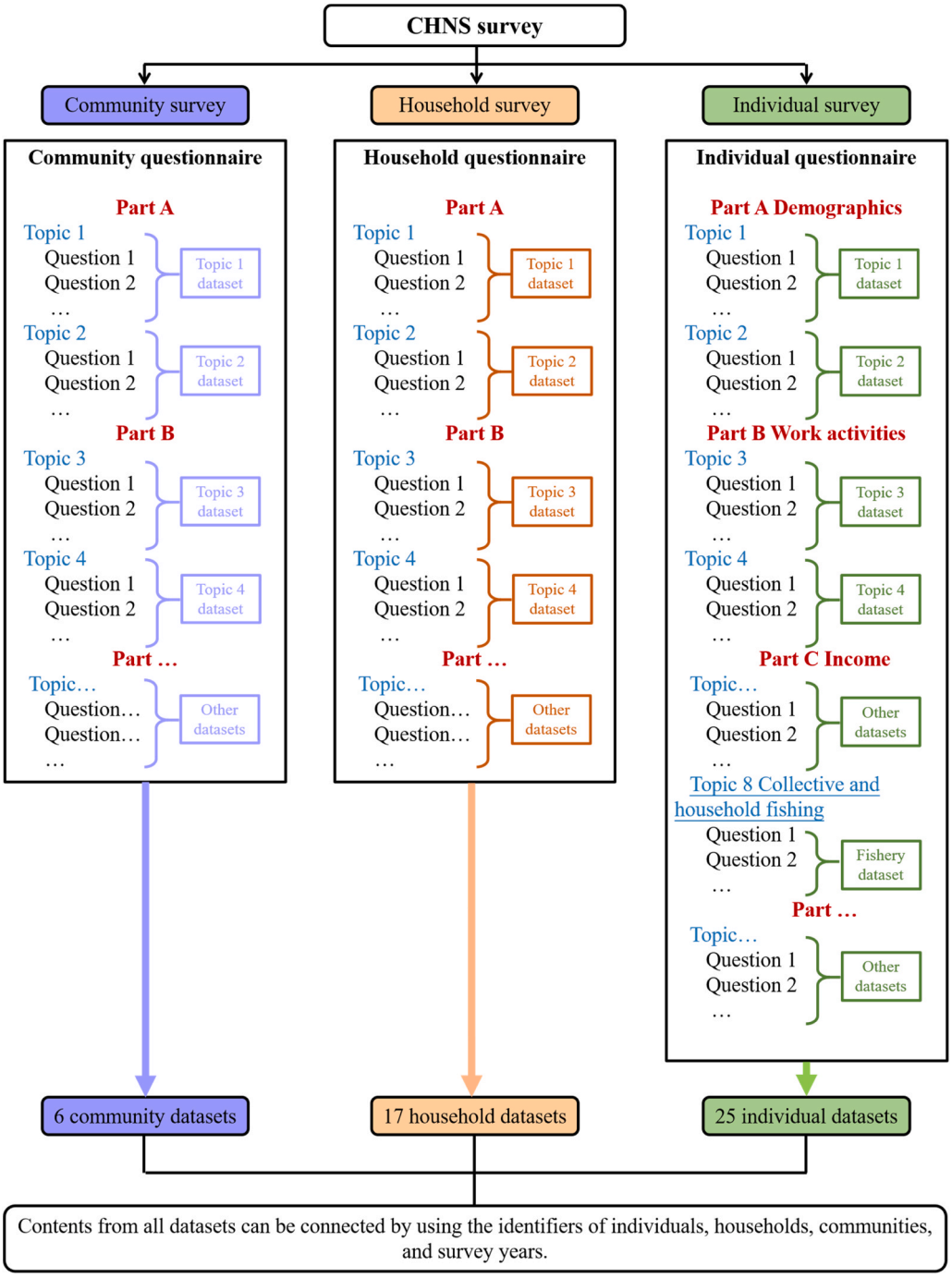

Figure A1. Structure of the China Health and Nutrition Survey (CHNS) and the corresponding datasets

Table A3
Total sample sizes and respondent retention of the subsets of fishery respondents in the China Health and Nutrition Survey (CHNS). See Table A2 for explanations

Year		1989	1991	1993	1997	2000	2004	2006	2009	2011	2015
Respondents		125	101	85	131	126	110	105	76	90	67
Respondents remaining in subsequent surveys	**1991**	33	–	–	–	–	–	–	–	–	–
	1993	26	32	–	–	–	–	–	–	–	–
	1997	11	16	25	–	–	–	–	–	–	–
	2000	5	12	14	38	–	–	–	–	–	–
	2004	8	7	15	19	23	–	–	–	–	–
	2006	5	5	9	15	19	35	–	–	–	–
	2009	2	3	4	8	14	21	27	–	–	–

(*continued on next page*)

Table A3 (*continued*)

Year		1989	1991	1993	1997	2000	2004	2006	2009	2011	2015
	2011	3	5	4	8	11	15	24	27	–	–
	2015	5	3	2	5	7	11	13	11	18	–
Respondents dropped out	**From fishery activity**	–	81	58	53	82	78	59	64	41	52
	From CHNS	–	11	11	7	11	25	16	14	8	20
Respondents added	**To fishery activity**	–	65	49	77	78	82	56	34	33	29
	To CHNS	–	3	4	29	10	5	14	15	30	20

A3. Recoding of education levels

The China Health and Nutrition Survey (CHNS) contains two questions about the education of participants: "How many years of formal education have you completed in a regular school?" and "What is the highest level of education you have attained?" Because the first question is not stated consistently across all surveys, we have used the answers to the second question to specify educational levels in the fishery population. For the purpose of assembling Fig. 3a, we have used the information from the questionnaires in conjunction with China's present education system to translate the level of education to the duration of education using the following key:

1. No graduation ("Not graduated from primary school", "没上过学") = 0 years
2. Primary-school graduation ("Graduated from primary school", "小学毕业") = 6 years
3. Junior-high-school graduation ("Lower middle school degree", "初中毕业" = 9 years
4. Senior-high-school graduation ("Upper middle school degree", "高中毕业") = 12 years
5. Technical or vocational graduation ("Technical or vocational degree", "中等技术学校或职业学校毕业") = 15 years
6. University or college graduation below master's degree ("University or college degree", "大专或大学毕业") = 16 years
7. University or college graduation at or above master's degree ("Master's degree or higher", "硕士及以上") = 20 years

Because there are very few individuals in the fishery population who have graduated at or above a master's degree, the sixth and the seventh levels above have been merged in our analysis. For each of the seven levels, we have listed the English term used in Fig. 3 followed in parentheses by the English term used in the English version of the CHNS questionnaires and by the Chinese term used in the Chinese version of the CHNS questionnaires as published by the CHNS Project.

A4. Definitions of the fishery population in the China Fisheries Yearbook

The term "fishery population" used in the China Fisheries Yearbook (CFY) is defined as including all persons who rely for their livelihoods on fishery production and related activities, which includes not only persons directly engaged in fishery production and related activities but also their dependents. Specifically, the following three groups, and only these, are included (Ministry of Agriculture Bureau of Fisheries, 2020):

(1) Persons fully engaged in fishery production and related activities.

(2) Persons partially engaged in fishery production and related activities for a cumulative period of three months or more during a whole year or with a net fishery income accounting for more than 50 % of their total net income.

(3) Persons supported by persons in (1) and (2). When such persons are part of families with both fishery workers and non-fishery workers, they are counted prorated according to the proportion of their family's net income accrued by fishery workers.

The term "population of fishery practitioners" used in the CFY from 2009 onwards and the term "fishery labor force" used in the CFY until 2008 are defined as including persons above 16 years of age who are engaged in fishery work and obtain labor remuneration or operating income from fishery activities. Since these two terms are defined identically, we treat them as interchangeable. Specifically, the following three groups, and only these, are included (Ministry of Agriculture Bureau of Fisheries, 2020):

(1) Full-time fishery practitioners: fishery practitioners engaged in fishery activities for six months or more during a whole year or dependent on fishery activities for more than 50 % of their livelihoods.

(2) Part-time fishery practitioners: fishery practitioners engaged in fishery activities for three to six months during a whole year or dependent on fishery activities for 20–50 % of their livelihoods.

(3) Temporary fishery practitioners: fishery practitioners engaged in fishery activities for three months or less during a whole year or dependent on fishery activities for less than 20 % of their livelihoods.

The term "traditional-fishery population" used in the CFY is defined as including the fishery population living in fishery townships and villages, having continuously engaged in fishery activities for more than three years, and mainly relying on fishery income (China Society of Fisheries, 2014). The fishery townships and villages are defined as the administrative areas in the countryside where (1) the proportion of workers engaged in fishery production and operation exceeds 50 % or (2) the value of the fishery production accounted for more than 50 % of the total value of agricultural and fishery production. Townships and villages that do not meet these criteria but have been mainly engaged in fishery and have been approved by the governmental departments of fishery administration at the next higher level as fishery townships and villages are also counted as fishery townships and fishery villages.

A5. Tabulation of raw data used and derived indicators shown in the figures based on weighted data

In this section, we provide the raw data used and the derived indicators shown in Figs. 1–6. All values shown in these figures and reported here are based on the weighted data, i.e., account for the survey weights we have developed.

Table A4
Sizes of the fishery population in China in different years based on the China Health and Nutrition Survey (CHNS) and as given in the China Fisheries Yearbook (CFY). Applying the proportion of the fishery population in the CHNS to the total population of China (China Statistical Yearbook; National Bureau of Statistics of China, 2020) gives a CHNS-based estimate of the size of the fishery population. For comparison, the sizes of the fishery population according to the alternative definitions used in the CFY are also shown

Year	Data in CHNS			Estimates based on CHNS		Data in CFY		
	Weighted number of fishery respondents	Weighted number of survey respondents	Weighted proportion of fishery respondents among survey respondents (%)	Size of total population of China (millions)	Estimated size of fishery population	Size of fishery population	Size of traditional fishery population	Number of fishery practitioners
1989	54	6540	0.7	1127	7781,092	11,404,035	–	8780,465
1990	–	–	–	1143	–	14,297,336	–	9092,926
1991	39	6573	0.6	1158	6694,425	13,610,687	–	9202,780
1992	–	–	–	1172	–	14,312,129	–	9664,534
1993	34	6153	0.5	1185	6357,049	15,441,581	–	10,071,681
1994	–	–	–	1199	–	16,045,869	–	10,843,890
1995	–	–	–	1211	–	16,827,473	–	11,428,655
1996	–	–	–	1224	–	18,618,697	–	12,076,192
1997	57	6384	0.8	1236	10,085,891	18,876,799	–	12,216,876
1998	–	–	–	1248	–	19,317,261	–	12,374,815
1999	–	–	–	1258	–	18,342,156	–	12,569,925
2000	60	7347	0.7	1267	9075,090	19,398,966	–	12,935,689
2001	–	–	–	1276	–	19,422,043	–	13,741,055
2002	–	–	–	1285	–	20,441,762	–	13,128,693
2003	–	–	–	1292	–	20,742,812	8100,829	12,947,336
2004	49	6901	0.9	1300	11,124,586	20,984,157	7962,146	13,018,332
2005	–	–	–	1308	–	20,676,428	7826,270	12,902,777
2006	36	8002	0.9	1314	11,690,078	20,400,467	7649,945	12,594,654
2007	–	–	–	1321	–	21,115,361	7822,751	13,168,614
2008	–	–	–	1328	–	20,961,324	7559,519	14,543,689
2009	35	7778	0.7	1335	8934,015	20,845,577	7456,534	13,847,271
2010	–	–	–	1341	–	20,810,260	7470,386	13,992,142
2011	46	11,337	0.6	1349	7574,724	20,606,894	7309,301	14,585,004
2012	–	–	–	1359	–	20,738,071	7235,753	14,440,510
2013	–	–	–	1367	–	20,659,375	7124,552	14,430,576
2014	–	–	–	1376	–	20,350,435	6864,047	14,290,201
2015	24	11,611	0.4	1383	5283,087	20,169,600	6784,648	14,148,513
2016	–	–	–	1392	–	19,734,145	6611,061	13,816,914
2017	–	–	–	1400	–	19,318,522	6521,381	13,593,913
2018	–	–	–	1405	–	18,786,757	6182,854	13,257,230
2019			–	1410	–	18,282,027	6004,984	12,916,952
2020			–	1412	–	17,207,654	5554,348	12,395,858

The estimated sizes of the fishery population (sixth column above) are shown in Fig. 1a and Fig. 6. The proportions of the fishery population estimated from the survey data (fourth column above) are shown in Fig. 1b and Fig. 6. The sizes of the fishery population (last three columns above) are shown in Fig. 1c. The proportions calculated by dividing the sizes of the fishery population in the CFY (last three columns above) by the size of the total population obtained from the China Statistical Yearbook (fifth column above) are shown in Fig. 1d. The weighted numbers of fishery respondents (second column above) and of total respondents (third column above) are calculated by summing the corresponding respondent weights. The weighted proportions of fishery respondents among survey respondents (fourth column above) are calculated using the weighted logistic regression models (Section 2.3.6).

Table A5
Characteristics of the weighted distributions of ages of fishery respondents, rural respondents, urban respondents, and all respondents of the China Health and Nutrition Survey (CHNS). For information on the sample sizes, see Table A4

Year	**Weighted mean ages (years)**					**Weighted proportions of population aged 65 years or older (%)**			
	Fishery respondents	**Rural respondents**	**Urban respondents**	**All respondents**	**Ratio between mean age of fishery respondents and mean age of all respondents**	**Fishery respondents**	**Rural respondents**	**Urban respondents**	**All respondents**
1989	38.4	28.2	31.7	29.3	1.311	2.7	5.2	7.3	5.8
1991	40.1	29.2	33.0	30.4	1.322	4.8	5.6	8.1	6.3
1993	41.6	30.2	34.3	31.4	1.325	2.5	6.1	8.4	6.7
1997	42.6	32.5	36.3	33.7	1.262	1.0	7.1	10.9	8.2
2000	42.9	34.0	38.6	35.4	1.211	2.7	7.9	12.8	9.3
2004	45.1	39.5	42.5	40.6	1.113	5.5	11.2	16.3	12.9
2006	47.7	41.6	43.9	42.5	1.124	8.7	12.7	17.0	14.1
2009	46.7	42.4	45.4	43.4	1.076	12.3	14.1	17.6	15.2
2011	48.9	43.4	46.0	44.4	1.101	9.6	15.3	18.8	16.5
2015	52.0	43.2	47.8	44.8	1.161	13.5	17.0	22.4	18.8

The mean ages (second to fifth column above) are shown in Fig. 2b. The proportions of the populations aged 65 years or older (last four columns

above) are shown in Fig. 2c. The ratios between the mean age of fishery respondents and the mean age of all respondents (sixth column above) are shown in Fig. 6, standardized relative to the first value of the time series.

Table A6
Characteristics of the weighted distributions of durations of education of fishery respondents, rural respondents, urban respondents, and all respondents of the China Health and Nutrition Survey (CHNS). For the description of how durations of education are estimated based on the level of educational attainment, see Section A3 of the Appendix

Year	Weighted mean durations of education (years)				Ratio between mean duration of education of fishery respondents and mean duration of education of all respondents
	Fishery respondents	Rural respondents	Urban respondents	All respondents	
1989	5.1	4.8	6.1	5.2	0.982
1991	4.8	5.2	6.6	5.6	0.861
1993	5.6	5.7	7.0	6.0	0.935
1997	6.1	5.8	7.1	6.2	0.987
2000	6.5	6.5	7.8	6.9	0.947
2004	6.9	6.6	8.2	7.2	0.956
2006	6.8	6.6	8.4	7.2	0.944
2009	6.9	6.7	8.5	7.3	0.952
2011	7.4	6.8	9.0	7.6	0.966
2015	7.6	7.6	9.5	8.2	0.929

The mean durations of education (second to fifth columns above) are shown in Fig. 3. The ratios between the mean duration of education of the fishery respondents and the mean duration of education of all respondents (last column above) are shown in Fig. 6, standardized relative to the first value of the time series.

Table A7
Characteristics of the weighted distributions of annual incomes of fishery respondents, rural respondents, urban respondents, and all respondents of the China Health and Nutrition Survey (CHNS). The income data are from the answers to the question about the "Total net individual income inflated to 2015" in the China Health and Nutrition Survey (CHNS)

Year	Weighted mean annual incomes (RMB)				Ratio between mean annual income of fishery respondents and mean annual income of all respondents
	Fishery respondents	Rural respondents	Urban respondents	All respondents	
1989	5252	2473	3086	2680	1.960
1991	3676	2576	3437	2823	1.302
1993	3444	2787	4049	3105	1.109
1997	6877	3841	5289	4249	1.619
2000	5819	4324	7909	5156	1.129
2004	4414	4696	10490	5936	0.744
2006	6398	6070	12724	7642	0.837
2009	13522	10209	18314	12292	1.100
2011	14614	12766	21460	15469	0.945
2015	13594	14040	25748	17604	0.772

The mean annual incomes (second to fifth columns above) are shown in Fig. 4. The ratios between the mean annual income of fishery respondents and the mean annual income of all respondents (last column) are shown in Fig. 6, standardized relative to the first value of the time series.

Table A8
Characteristics of the weighted distributions of occupational mobility of fishery respondents and all respondents of the China Health and Nutrition Survey (CHNS) using the two-survey timeframe. For definitions, see Section 2.2.5

Year	Weighted numbers of transitions of fishery respondents			Weighted numbers of transitions of all respondents			Proportion of "Left" transitions among all transitions		Ratio between the proportion of "Left" transitions of fishery respondents and the proportion of "Left" transitions of all respondents
	"Left" transitions	"Stayed" transitions	All transitions	"Left" transitions	"Stayed" transitions	All transitions	Fishery respondents	All respondents	
1989	–	–	–	–	–	–	–	–	–
1991	30	12	42	1299	2313	3612	0.684	0.353	1.938
1993	18	18	36	1035	2199	3234	0.619	0.320	1.935
1997	19	7	26	712	1510	2222	0.714	0.321	2.225
2000	33	17	50	882	1753	2635	0.694	0.335	2.071
2004	31	9	40	597	1218	1815	0.758	0.329	2.303
2006	25	10	35	469	1024	1493	0.618	0.314	1.969
2009	24	9	33	485	936	1421	0.699	0.342	2.043
2011	23	13	36	643	1247	1890	0.609	0.340	1.791
2015	20	8	28	733	838	1571	0.745	0.469	1.590

The proportions of transitions of fishery respondents calculated by dividing the numbers of transitions of the fishery population (second and third columns above) by the numbers of all transitions of the fishery population (fourth column above) using the two-survey timeframe are shown in Fig. 5b. The ratios between the proportion of "Left" transitions of the fishery respondents and the proportion of "Left" transitions of all respondents are shown

in Fig. 6, standardized relative to the first value of the time series.

A6. Description of three measures of engagement duration

In Section 2.2.5, we define three alternative quantitative measures of the duration of engagement in the fishing sector or of participation in the CHNS. Figure A2 explains in detail, using an illustrative example, how we determine these three measures of duration and the corresponding weights.

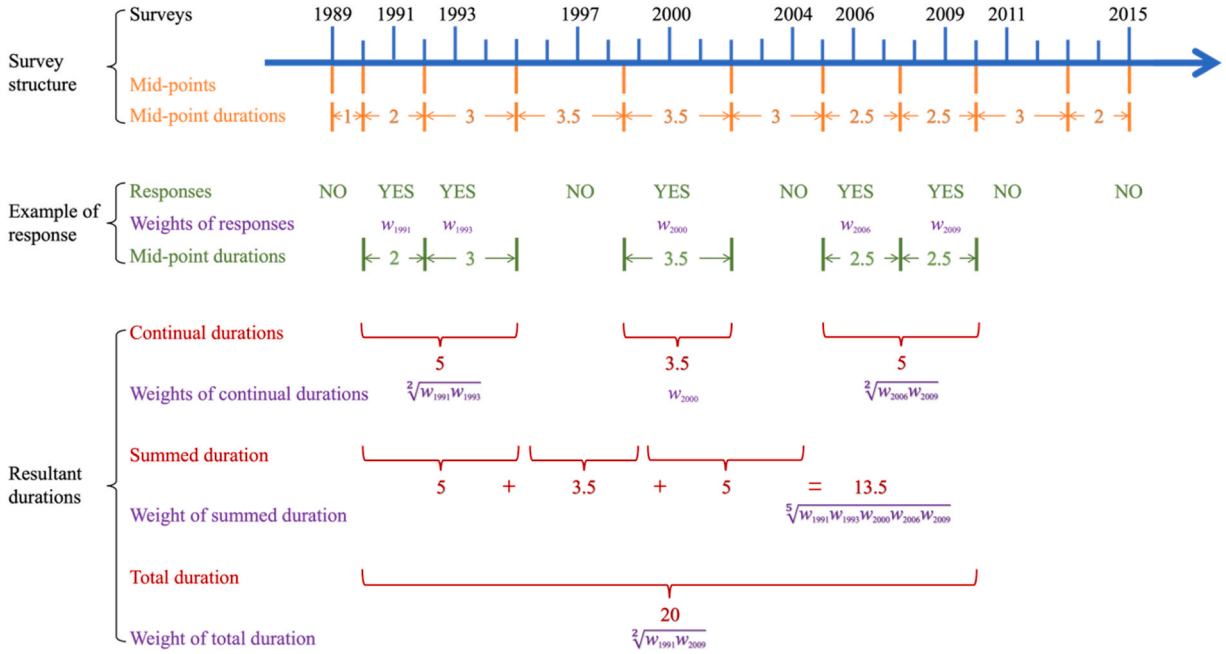

Figure A2. Schematic description of three alternative quantitative measures of engagement duration. As an example, we consider a recurrent CHNS respondent who reported his or her engagement in the fishing sector in the five surveys of 1991, 1993, 2000, 2006, and 2009 and either did not respond or responded without reporting an engagement in the fishing sector in the five surveys of 1989, 1997, 2004, 2011, and 2015 (row "Responses", in green). The weights of these responses depend on the respondent's province and year of response (row "Weights of responses", in purple). Based on the mid-points between each pair of adjacent surveys (row "Mid-points", in yellow), the mid-point durations (row "Mid-point durations", in yellow) of engagement in the fishing sector for this respondent are 2, 3, 3.5, 2.5, and 2.5 years, respectively (row "Mid-point durations", in green). According to the three alternative quantitative measures of the duration of fishery occupation defined in Section 2.2.5, for this respondent, the continual durations of fishery occupation are 5, 3.5, and 5 years (row "Continual durations", in red), the summed duration of fishery occupation is 13.5 years (row "Summed duration", in red), and the total duration of fishery occupation is 20 years (row "Total duration", in red). The weights of these durations are the geometric means of the weights of the involved responses (rows "Weights of continual durations", "Weight of summed duration", and "Weight of total duration", in purple). The shown example for durations of fishery occupation applies analogously to durations of CHNS participation by interpreting the information in the row "Responses" accordingly

A7. Definition of the median of the measures of engagement duration

Since the durations of fishery occupation and CHNS participation that we can estimate from the CHNS are constrained and artificially homogenized by the few years in which surveys were conducted, we consider the histograms of these durations as for grouped data. Therefore, we define the median duration as $l_m + (u_m - l_m)(1/2 - \sum f_i)/f_m$, where l_m is the lower limit of the median class, u_m is the upper limit of the median class, $\sum f_i$ is the sum of the frequencies of all classes below the median class, and f_m is the frequency of the median class.

A8. Provincial distributions of proportions and weights in the fishery sample and total sample

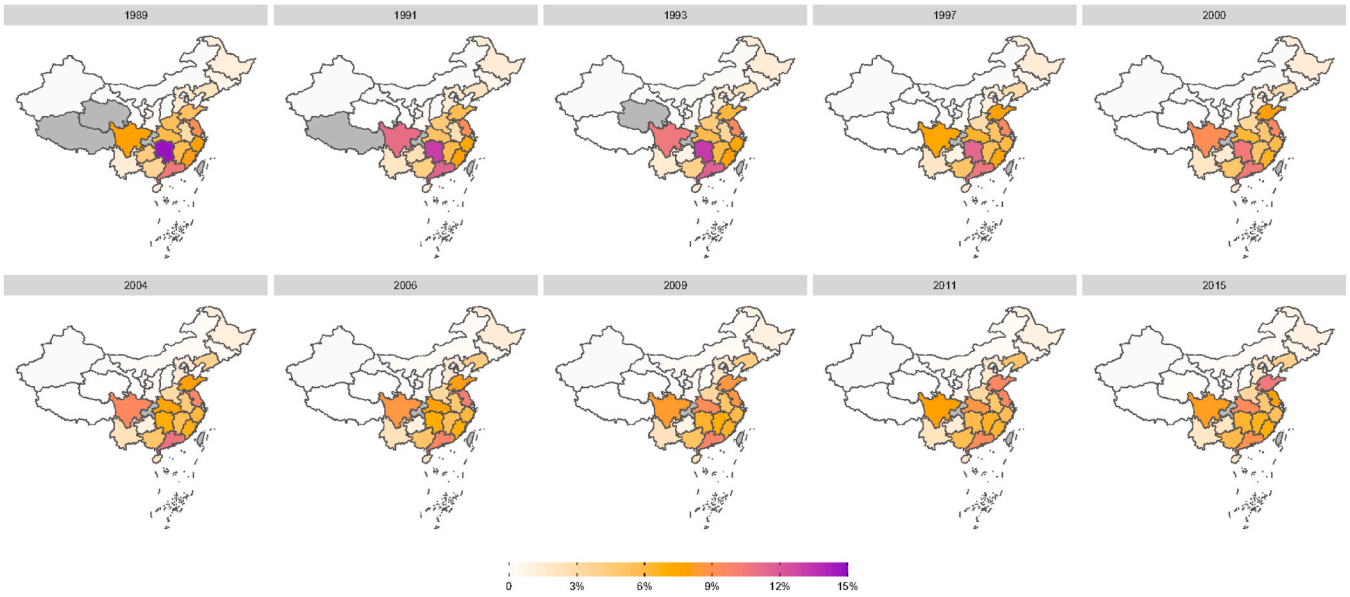

Figure A3. Distribution of the proportion $p_{i,j}$ of individuals in the fishery population in province i in year j

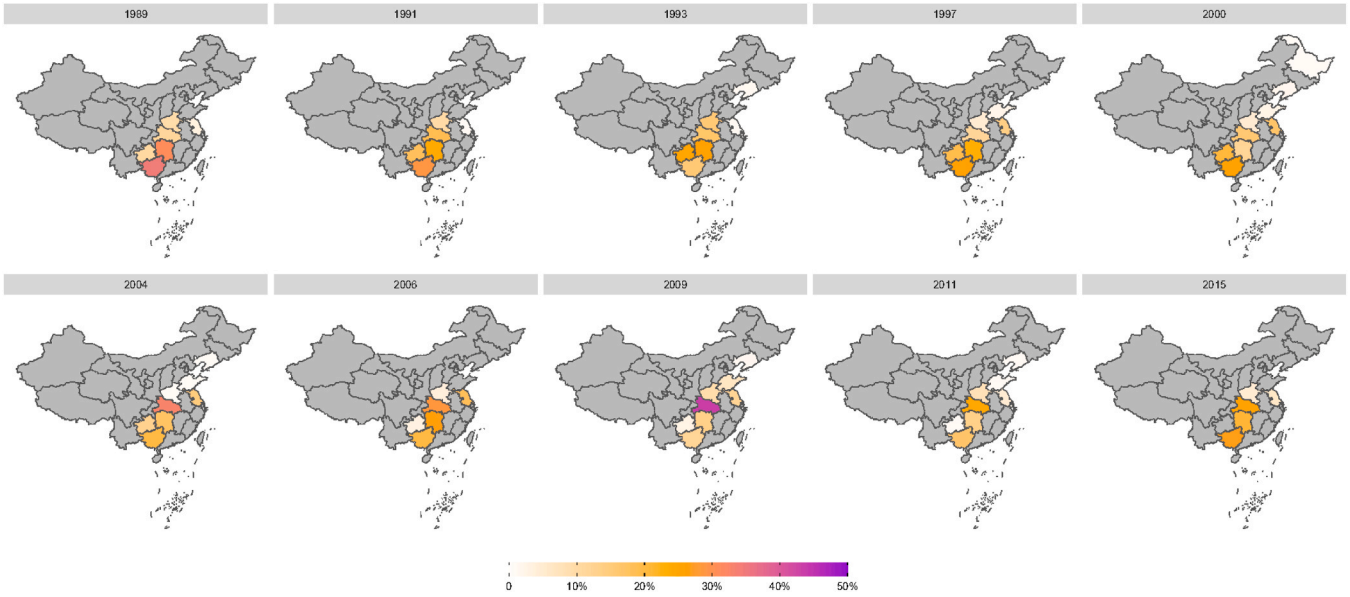

Figure A4. Distribution of the proportion $s_{i,j}$ of individuals in the CHNS fishery sample in province i in year j

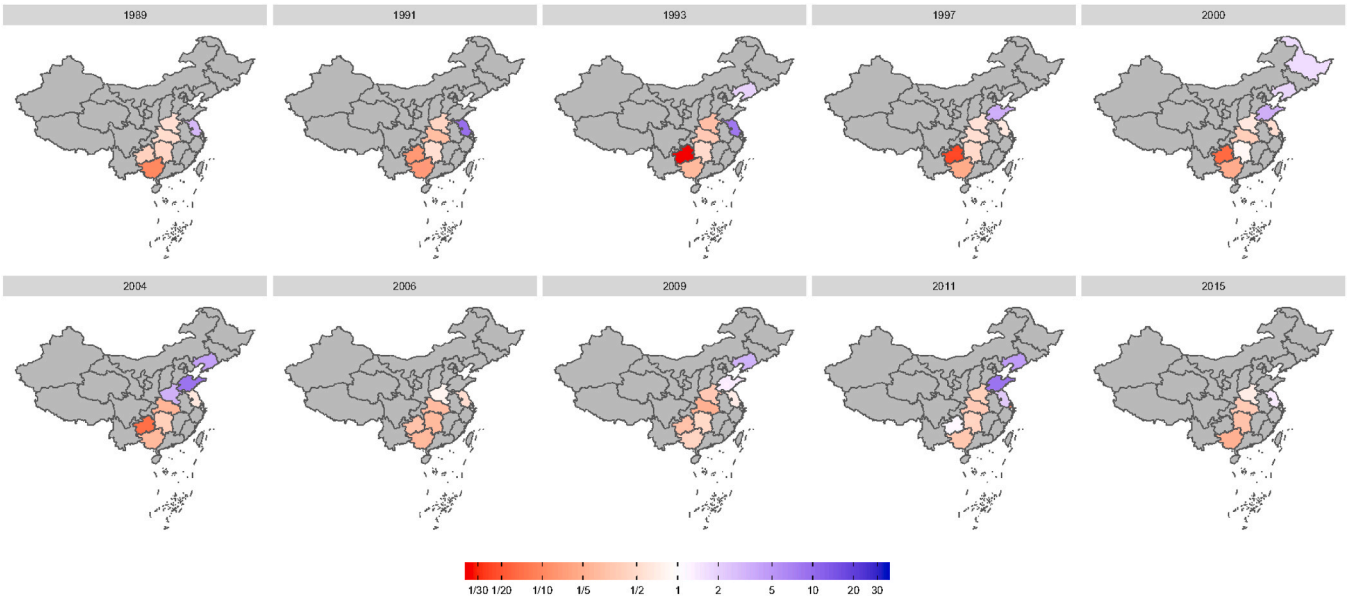

Figure A5. Distribution of the survey weights $w_{i,j} = p_{i,j}/s_{i,j}$ of the CHNS fishery sample in province i in year j. The color coding is based on logarithmic scaling: red colors indicate that the province was overrepresented in the CHNS fishery sample of the considered survey year, while blue colors indicate underrepresentation

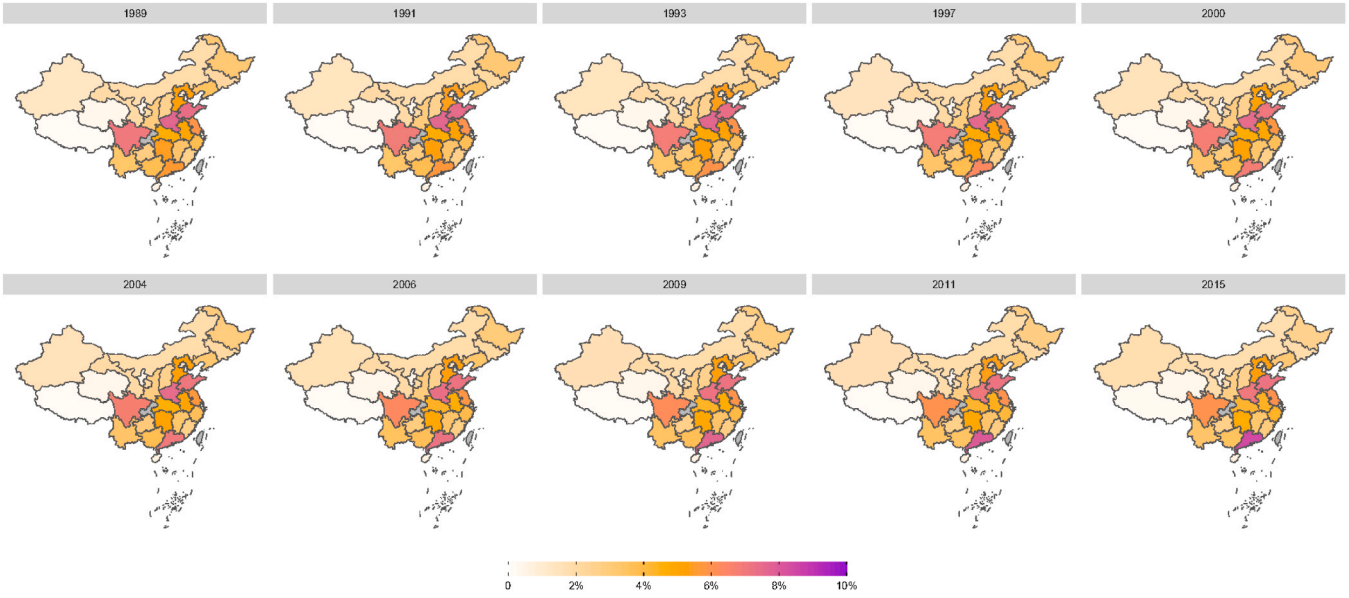

Figure A6. Distribution of the proportion $p_{i,j}$ of individuals in the total population in province i in year j

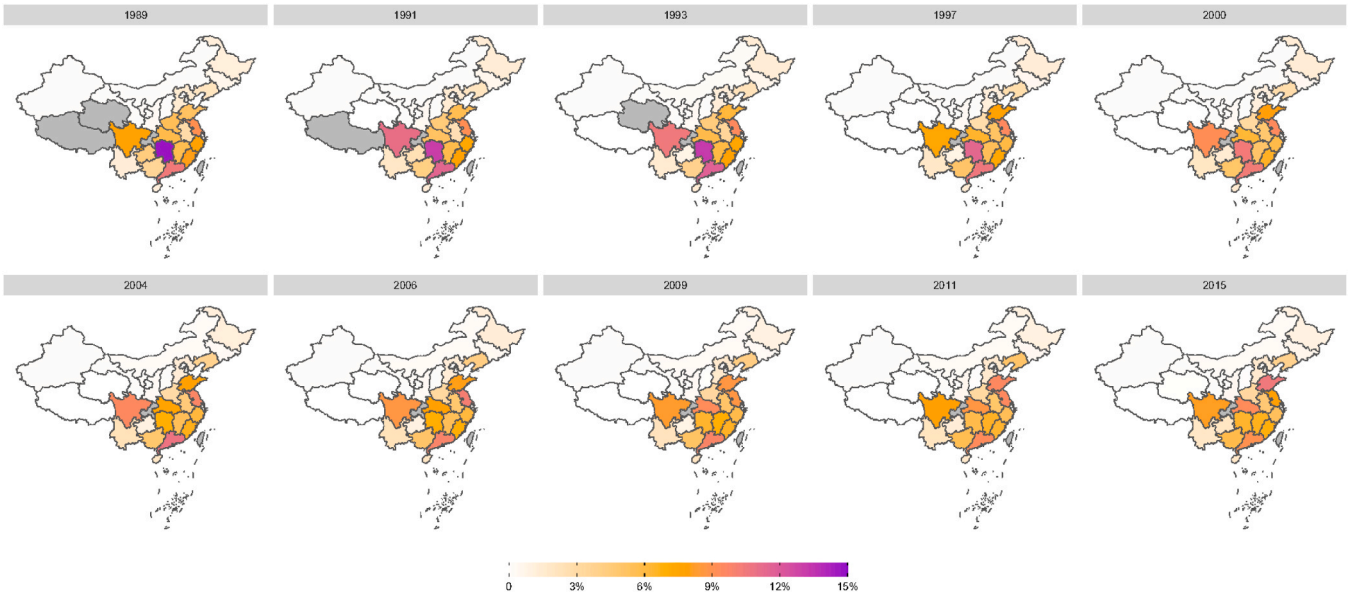

Figure A7. Distribution of the proportion $s_{i,j}$ of individuals in the CHNS total sample in province i in year j

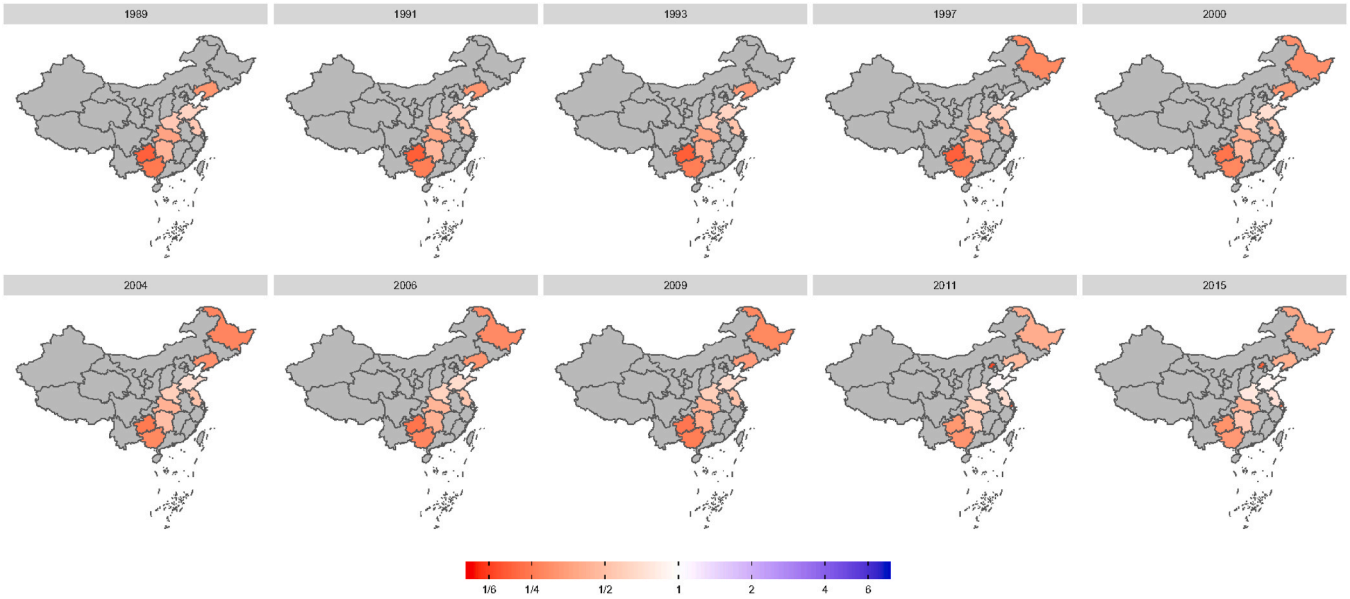

Figure A8. Distribution of the survey weights $w_{i,j} = p_{i,j}/s_{i,j}$ of the CHNS total sample in province i in year j. The color scaling is based on logarithmic scaling: red colors indicate that the province was overrepresented in the CHNS total sample of the considered survey year, while blue colors indicate underrepresentation

A9. Figures based on unweighted data

In this section, we show, based on unweighted data, the analogues of all figures shown in the Results section.

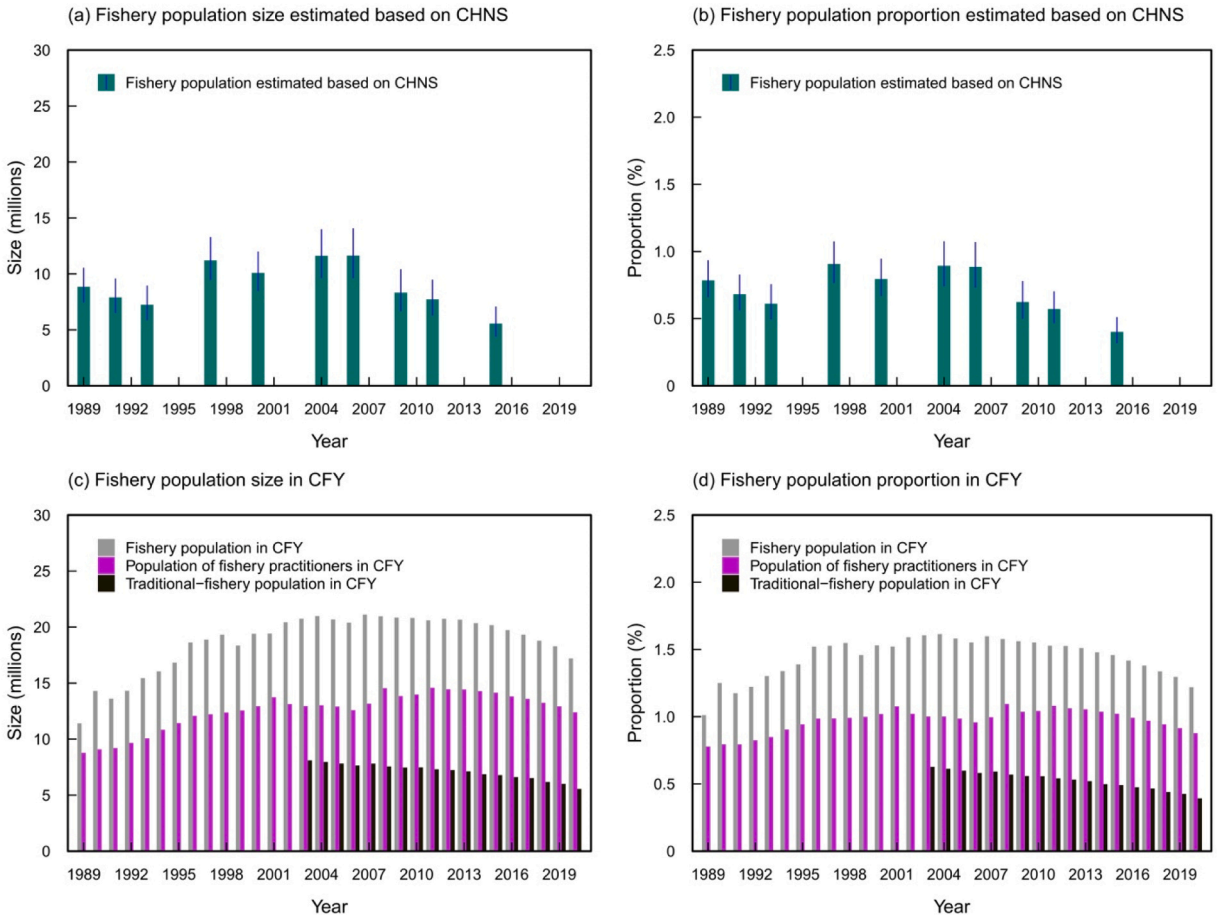

Figure A9. Development of the size of China's fishery population and of its proportion of China's total population. For detailed information, see the caption of Fig. 1

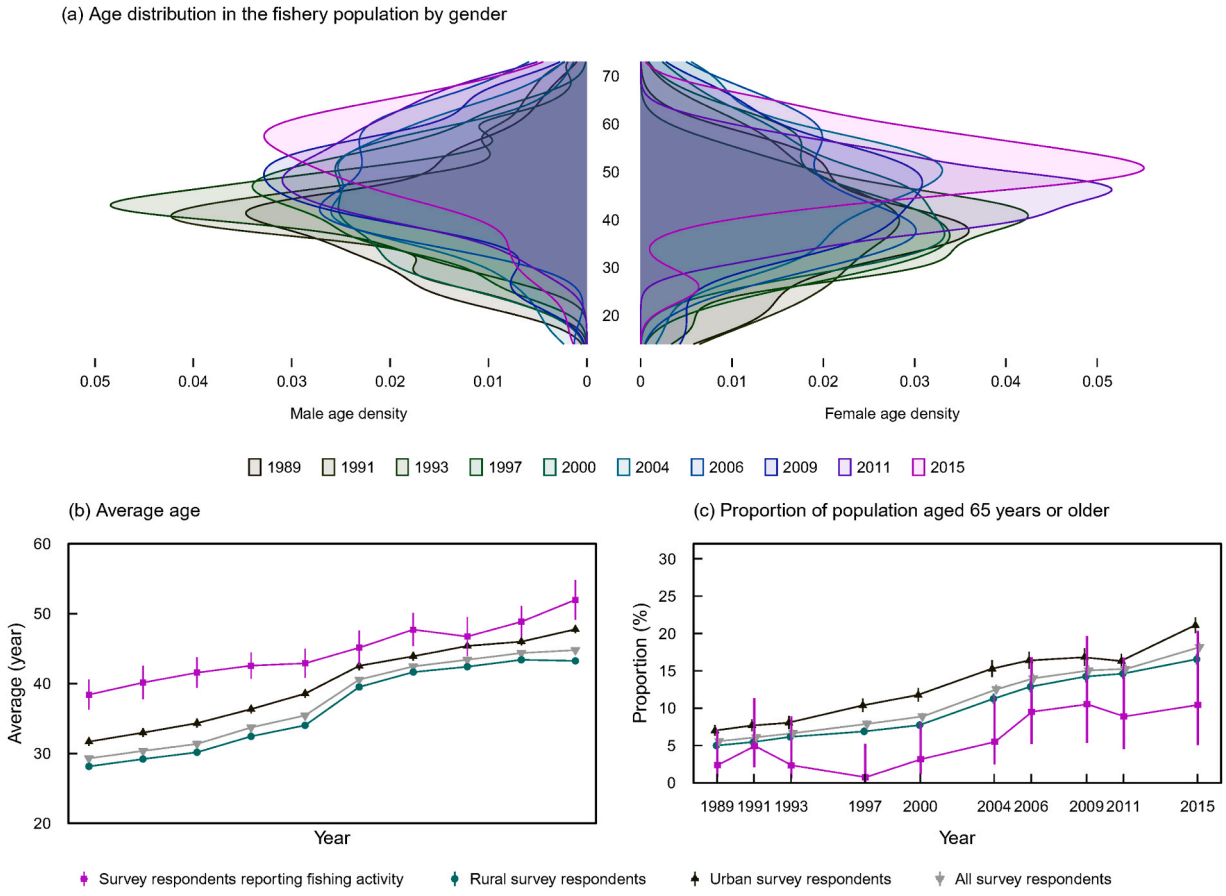

Figure A10. Age distributions in the fishery population and aging trends in the fishery, rural, urban, and total populations, based on data from the China Health and Nutrition Survey (CHNS). For detailed information, see the caption of Fig. 2

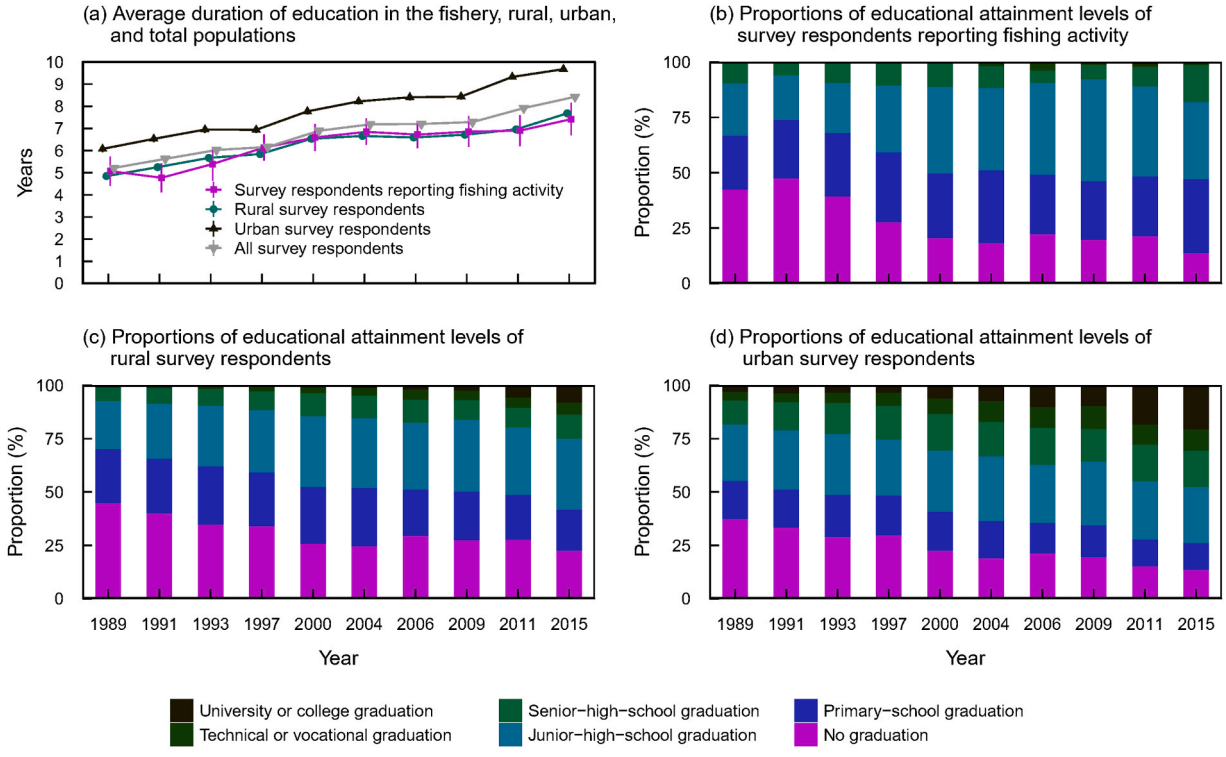

Figure A11. Educational status of the fishery, rural, and urban populations, based on data from the China Health and Nutrition Survey (CHNS). For detailed information, see the caption of Fig. 3

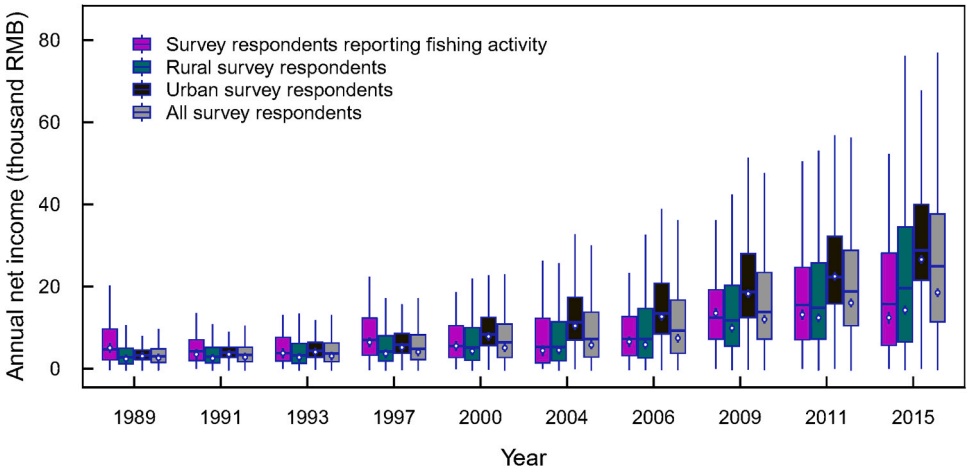

Figure A12. Net annual incomes of the rural, urban, fishery, and total populations, based on data from the China Health and Nutrition Survey (CHNS). For detailed information, see the caption of Fig. 4

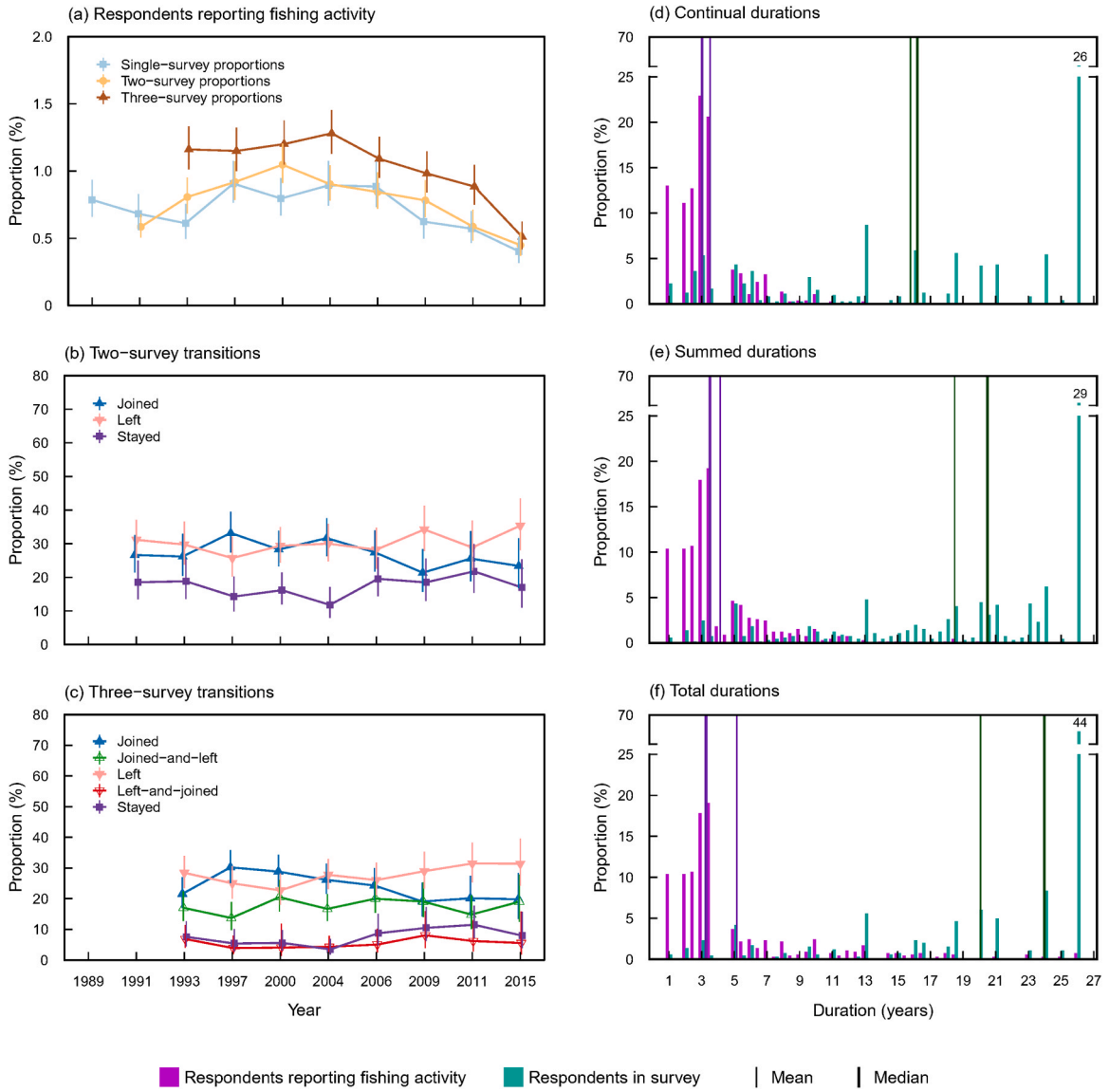

Figure A13. Directions and frequencies of occupational transitions (left column) and durations of fishery occupation (right column), based on data from the China Health and Nutrition Survey (CHNS). For detailed information, see the caption of Fig. 5

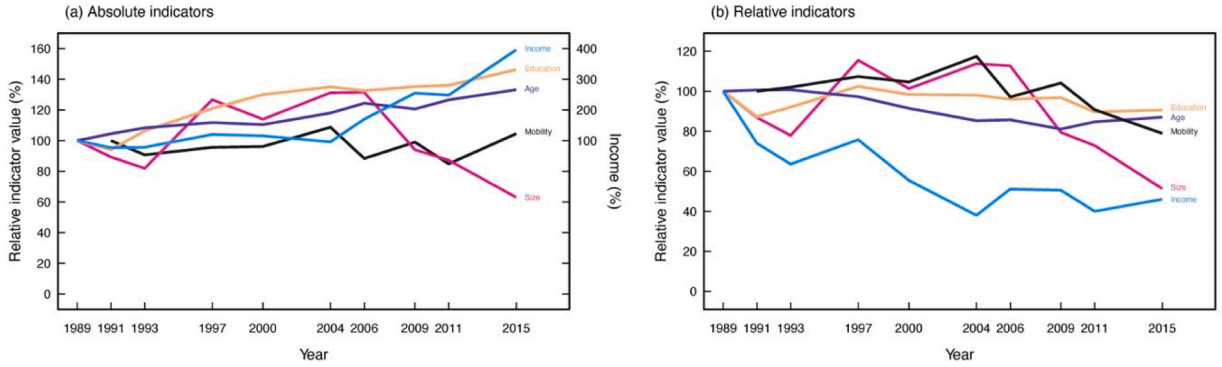

Figure A14. Time series of key indicators of the fishery population's size (magenta), age (purple), education (orange), income (blue), and occupational mobility (black). (a) Indicators directly describe fishery population. (b) Indicators describe the fishery population relative to China's total population. 'Mobility' in panel a represents the proportion of 'Left' transitions among 'Left' and 'Stayed' transitions in the fishery population using the two-survey timeframe. 'Mobility' in panel b represents the ratio between the aforementioned proportion of 'Left' transitions of the fishery respondents and the corresponding proportion of 'Left' transitions of the total survey respondents. All time series are standardized with respect to their starting values (first year = 100 %)

A10. Tabulation of raw data used and derived indicators shown in the figures based on unweighted data

Table A9
Sizes of the fishery population in China in different years based on the China Health and Nutrition Survey (CHNS) and as given in the China Fisheries Yearbook (CFY). For detailed information, see the caption of Table A4

Year	Data in CHNS			Estimates based on CHNS		Data in CFY		
	Number of fishery respondents	Number of survey respondents	Proportion of fishery respondents among survey respondents (%)	Size of total population of China (millions)	Estimated size of fishery population	Size of fishery population	Size of traditional fishery population	Number of fishery practitioners
1989	125	15,907	0.8	1127	8856,479	11,404,035	–	8780,465
1990	–	–	–	1143	–	14,297,336	–	9092,926
1991	101	14,797	0.7	1158	7905,740	13,610,687	–	9202,780
1992	–	–	–	1172	–	14,312,129	–	9664,534
1993	85	13,895	0.6	1185	7250,050	15,441,581	–	10,071,681
1994	–	–	–	1199	–	16,045,869	–	10,843,890
1995	–	–	–	1211	–	16,827,473	–	11,428,655
1996	–	–	–	1224	–	18,618,697	–	12,076,192
1997	131	14,441	0.9	1236	11,214,602	18,876,799	–	12,216,876
1998	–	–	–	1248	–	19,317,261	–	12,374,815
1999	–	–	–	1258	–	18,342,156	–	12,569,925
2000	126	15,831	0.8	1267	10,087,562	19,398,966	–	12,935,689
2001	–	–	–	1276	–	19,422,043	–	13,741,055
2002	–	–	–	1285	–	20,441,762	–	13,128,693
2003	–	–	–	1292	–	20,742,812	8100,829	12,947,336
2004	110	12,308	0.9	1300	11,617,388	20,984,157	7962,146	13,018,332
2005	–	–	–	1308	–	20,676,428	7826,270	12,902,777
2006	105	11,860	0.9	1314	11,637,470	20,400,467	7649,945	12,594,654
2007	–	–	–	1321	–	21,115,361	7822,751	13,168,614
2008	–	–	–	1328	–	20,961,324	7559,519	14,543,689
2009	76	12,178	0.6	1335	8328,297	20,845,577	7456,534	13,847,271
2010	–	–	–	1341	–	20,810,260	7470,386	13,992,142
2011	90	15,725	0.6	1349	7721,742	20,606,894	7309,301	14,585,004
2012	–	–	–	1359	–	20,738,071	7235,753	14,440,510
2013	–	–	–	1367	–	20,659,375	7124,552	14,430,576
2014	–	–	–	1376	–	20,350,435	6864,047	14,290,201
2015	67	16,622	0.4	1383	5575,649	20,169,600	6784,648	14,148,513
2016	–	–	–	1392	–	19,734,145	6611,061	13,816,914
2017	–	–	–	1400	–	19,318,522	6521,381	13,593,913
2018	–	–	–	1405	–	18,786,757	6182,854	13,257,230
2019				1410	–	18,282,027	6004,984	12,916,952
2020				1412	–	17,207,654	5554,348	12,395,858

Table A10
Characteristics of the distributions of ages of fishery respondents, rural respondents, urban respondents, and all respondents of the China Health and Nutrition Survey (CHNS). For detailed information, see the caption of Table A5

Year	Mean ages (years)					Proportions of population aged 65 years or older (%)			
	Fishery respondents	Rural respondents	Urban respondents	All respondents	Ratio between mean age of fishery respondents and mean age of all respondents	Fishery respondents	Rural respondents	Urban respondents	All respondents
1989	38.3	28.0	31.0	29.0	1.319	2.4	5.0	7.0	5.6
1991	40.0	29.1	32.3	30.1	1.328	5.0	5.5	7.7	6.1
1993	41.4	30.1	33.6	31.2	1.329	2.4	6.1	8.0	6.7
1997	42.8	32.2	35.6	33.3	1.283	0.8	6.8	10.2	7.9
2000	42.3	33.8	37.7	35.0	1.207	3.2	7.7	11.7	8.9
2004	45.2	39.1	42.0	40.1	1.125	6.4	11.2	15.2	12.5
2006	47.6	41.2	43.7	42.1	1.131	9.5	12.8	16.3	14.0
2009	46.2	42.2	45.1	43.1	1.070	10.5	14.2	16.7	15.1
2011	48.4	42.5	44.5	43.3	1.118	8.9	14.6	16.3	15.3
2015	51.0	42.9	46.9	44.4	1.148	10.4	16.5	21.1	18.2

Table A11
Characteristics of the distributions of durations of education of fishery respondents, rural respondents, urban respondents, and all respondents of the China Health and Nutrition Survey (CHNS). For detailed information, see the caption of Table A6

Year	Mean durations of education (years)				Ratio between mean duration of education of fishery respondents and mean duration of education of all respondents
	Fishery respondents	Rural respondents	Urban respondents	All respondents	
1989	5.1	4.8	6.1	5.2	0.972
1991	4.8	5.2	6.5	5.6	0.848
1993	5.4	5.7	6.9	6.0	0.895
1997	6.1	5.8	6.9	6.2	0.995
2000	6.6	6.5	7.8	6.9	0.956
2004	6.8	6.7	8.2	7.2	0.953
2006	6.7	6.6	8.4	7.2	0.933
2009	6.9	6.7	8.4	7.3	0.941
2011	6.9	7.0	9.3	7.9	0.871
2015	7.4	7.7	9.7	8.4	0.880

Table A12
Characteristics of the distributions of annual incomes of fishery respondents, rural respondents, urban respondents, and all respondents of the China Health and Nutrition Survey (CHNS). For detailed information, see the caption of Table A7

Year	Mean annual incomes (RMB)				Ratio between mean annual income of fishery respondents and mean annual income of all respondents
	Fishery respondents	Rural respondents	Urban respondents	All respondents	
1989	5048	2371	3058	2600	1.942
1991	3491	2538	3488	2804	1.245
1993	3767	2731	4040	3059	1.231
1997	6410	3652	5164	4073	1.574
2000	5511	4265	7831	5075	1.086
2004	4381	4510	10429	5755	0.761
2006	6536	5843	12689	7413	0.882
2009	13477	9884	18256	11982	1.125
2011	13153	12381	22466	15999	0.822
2015	12414	14254	26576	18528	0.670

Table A13
Characteristics of the distributions of occupational mobility of fishery respondents and all respondents of the China Health and Nutrition Survey (CHNS) using the two-survey timeframe. For detailed information, see the caption of Table A8

Year	Numbers of transitions of fishery respondents	Numbers of transitions of all respondents	Proportion of "Left" transitions among all transitions	Ratio between the proportion of "Left" transitions of fishery respondents and the proportion of "Left" transitions of all respondents

(*continued on next page*)

Table A13 (*continued*)

Year	Numbers of transitions of fishery respondents			Numbers of transitions of all respondents			Proportion of "Left" transitions among all transitions		Ratio between the proportion of "Left" transitions of fishery respondents and the proportion of "Left" transitions of all respondents
	"Left" transitions	"Stayed" transitions	All transitions	"Left" transitions	"Stayed" transitions	All transitions	Fishery respondents	All respondents	
	"Left" transitions	"Stayed" transitions	All transitions	"Left" transitions	"Stayed" transitions	All transitions	Fishery respondents	All respondents	
1989	–	–	–	–	–	–	–	–	–
1991	81	33	114	3094	5678	8772	0.711	0.353	2.014
1993	58	32	90	2462	5388	7850	0.644	0.314	2.055
1997	53	25	78	1678	3663	5341	0.679	0.314	2.163
2000	82	38	120	2051	4276	6327	0.683	0.324	2.108
2004	78	23	101	1388	2863	4251	0.772	0.327	2.365
2006	59	35	94	1124	2380	3504	0.628	0.321	1.957
2009	64	27	91	1147	2273	3420	0.703	0.335	2.097
2011	41	27	68	1280	2601	3881	0.603	0.330	1.828
2015	52	18	70	1634	1863	3497	0.743	0.467	1.590

Data availability

The authors do not have permission to share data.

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