An assessment of changes in the daytime, boat-based, recreational fishery of the Tuross Lake estuary following the establishment of a 'Recreational Fishing Haven'

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EXECUTIVE SUMMARY

Resource sharing and the allocation of fisheries resources between recreational and commercial user groups has long been a contentious management issue in New South Wales (NSW). The introduction of a general recreational fishing fee in March 2001 generated considerable funding that was used to undertake significant changes in the management of fisheries in NSW. The Tuross Lake estuary was zoned a 'Recreational Fishing Haven' (RFH) following extensive community consultation. This management initiative changed the allocation of fisheries resources in this waterway between the recreational and commercial sectors. This major re-allocation of access to the estuarine fisheries resources in Tuross Lake has undoubtedly created additional recreational fishing opportunities. Thus, there was an important need to assess whether the recreational fisheries in this RFH were improving and providing better quality recreational fishing. This report focuses on comparisons made between two separate daytime, boat-based, recreational fishing surveys of the Tuross Lake estuary. The first annual survey was done during the pre-RFH period (March 1999 to February 2000) and the second annual survey was done during the post-RFH period (December 2003 to November 2004). These annual surveys provide a snapshot of the recreational fishery before RFH implementation and after RFH implementation. The same on-site, survey design was used in both surveys. The boat-based fishery was assessed by using a access(effort)-access(harvest) design combination and stratified random sampling methods. Auxiliary datasets consisting of automated traffic records at public boat ramps (both survey years) and boat-hire records (survey year 1 only) were used to supplement the survey data and improve the accuracy and precision of fishing effort and harvest estimates within this recreational fishery.

The two recreational fishing surveys provide evidence of a relatively productive recreational fishery in the Tuross Lake estuary. Comparisons made between the two separate daytime, boat-based, recreational fishing surveys indicate that the post-RFH recreational fishery was very different to the fishery that had existed prior to the implementation of the RFH. We documented statistically significant increases in recreational harvest for some prized recreational species and also some significant decreases for some other important recreational species. Overall, the indicators of recreational fishing quality that we examined indicated that the post-RFH fishery had improved in many ways since the pre-RFH survey period. A summary of the evidence provided in this report is that:

(a) the recreational harvest (number and weight) in both survey years was dominated by a relatively small number of taxa, however, the relative contribution of these dominant taxa changed markedly between survey years. These changes occurred even though there was no significant difference, by number, between survey years in the total annual harvest. A significant increase, by weight (41.6%), in the annual harvest of fish, crabs and cephalopods was recorded during the post-RFH survey year;

(b) the recreational harvest of dusky flathead and sand whiting (number and weight), yellowfin bream (number only) and sand mullet (weight only) had increased significantly during the post-RFH survey year;

(c) the recreational harvest of luderick, yelloweye mullet, large-toothed flounder and small-toothed flounder, by number and weight, had decreased significantly during the post-RFH survey year;

(d) fishing effort (number of boat trips) increased significantly by about 25.2% during the post-RFH survey year;

(e) significant harvest rate differences between corresponding seasons in the two survey years were detected. These significant differences in seasonal harvest rates between survey years indicate that major changes have occurred in the fishery since the pre-RFH survey period;

(f) comparisons of length frequency information, mean and median lengths between survey years indicated that most species were harvested at larger sizes during the post-RFH survey year. The mean and median sizes of dusky flathead, sand whiting, river garfish and large-toothed flounder were all larger during the second survey year. Similarly, the mean and median sizes of sand mullet, tailor, yelloweye mullet and small-toothed flounder were larger during the post-RFH survey year but these comparisons should be treated with caution because of the small sample sizes (<50 fish per species) in one of the survey years;

(g) the dusky flathead population within the Tuross Lake estuary was fished heavily prior to the implementation of the RFH when commercial fishing was still allowed. The length frequency data indicate that dusky flathead were growth overfished at the time of the pre-RFH survey. The relatively small improvement measured during the post-RFH survey indicates that the increase in recreational fishing effort of about 25% has been sufficiently large to offset most of the potential gain made by removing commercial effort.

This study provides annual snapshots (point estimates) of the daytime, boat-based recreational fishery in the Tuross Lake estuary prior to and following the establishment of the waterway as a RFH. On-site surveys of recreational fishing are valuable tools for collecting information to describe the status of a fishery and any changes that may have occurred since previous survey periods. On-site surveys of the recreational fishery should be repeated regularly (every 3-5 years) to monitor the recreational fishery in the Tuross Lake estuary.

1. INTRODUCTION

Resource sharing and the allocation of fisheries resources between recreational and commercial user groups has long been a contentious management issue in New South Wales (e.g. NSW Parliament - Fisheries Inquiry Commission 1880). Since the Fisheries Inquiry of 1880, the recreational sector has continued to grow and this has led to increased conflict with the commercial sector as both groups strive to maximise their share of limited fisheries resources. Historically, allocation disputes between the commercial and recreational sectors have been focused on estuarine fisheries near large metropolitan areas, such as Botany Bay and Sydney Harbour (Ruello and Henry 1977, State Pollution Control Commission 1981, Henry 1984). More recently, the focus of this allocation debate has expanded to include estuarine fisheries throughout NSW.

In July 1996, the NSW government commissioned a major review of commercial and recreational fishing practices, existing fisheries management policies and the status of estuarine fisheries resources on the south coast of NSW (Gibbs 1997). This review was initiated because of numerous complaints about the use of shared fisheries resources and concerns about their sustainability (Gibbs 1997). The report of the review findings documented the conflicting views of commercial and recreational fishing groups and their preferred management options. The report also provided summaries of commercial production and effort data for the south coast estuaries. The Tuross Lake estuary was identified as the third most important south coast estuary on the basis of average annual commercial catch but the fishery was declining (Gibbs 1997). Commercial catch rates for all of the main species in Tuross Lake (except prawns) showed consistent declines over the twelve year period, 1984/85 to 1995/96 (Gibbs 1997). The commercial catch rates for dusky flathead, bream and luderick were shown to have fallen by at least 50% during the twelve year period (Gibbs 1997). Thus, there was a need to collect quantitative information to describe the recreational fishery of the Tuross Lake estuary and to compare the relative size of commercial and recreational harvests. A survey of daytime, boat-based, recreational fishing, was started in March 1999 and completed at the end of February 2000. This survey provided the baseline quantitative information needed to describe and assess the status of the boat-based recreational fishery in Tuross Lake (Steffe and Chapman unpublished data).

The introduction of a general recreational fishing fee in March 2001 generated funding that was used to undertake significant changes in the management of fisheries in NSW. Extensive community consultation was undertaken to identify suitable estuarine areas that could be zoned 'Recreational Fishing Havens' (RFH). The intent was that areas declared 'Recreational Fishing Havens' would improve recreational fishing opportunities when commercial fishing was removed from them. Thirty locations, including the whole of the Tuross Lake estuary, were declared 'Recreational Fishing Havens' during the period May to September 2002. This resulted in a total estuarine area of 27% being made substantially free of commercial fishing (some RFH areas still have limited commercial fishing). This major re-allocation of access to the estuarine fisheries resources in NSW has undoubtedly created additional recreational fishing opportunities. Thus, there was an important need to assess whether these 'Recreational Fishing Havens' were actually improving the recreational fisheries.

The previous recreational fishing survey done in the Tuross Lake estuary during 1999-2000 (Steffe and Chapman unpublished data) provided a pre-RFH benchmark that could be used to assess any post-RFH changes that had occurred in the fishery. Hence, another survey of recreational fishing was done so that we could assess changes in the harvest, effort and quality of fishing that had occurred after the implementation of the RFH.

2. OBJECTIVES

The principal aims of this project were:

- To estimate the level of daytime, boat-based, recreational fishing effort and harvest in the Tuross Lake estuary during the annual period, December 2003 to November 2004 inclusive.

- To assess changes in the daytime, boat-based, fishing effort and harvest of recreational fishers that had occurred since the establishment of Tuross Lake as a Recreational Fishing Haven in May 2002.

- To use selected indicators of recreational fishing quality to assess changes in the Tuross Lake boat-based fishery after its establishment as a Recreational Fishing Haven.

3. METHODS

3.1. General comments

Data comparisons are derived from two separate recreational fishing surveys of Tuross Lake. The first annual survey was carried out during March 1999 to February 2000 inclusive and represents a snapshot of the boat-based recreational fishery before the area was declared a Recreational Fishing Haven. The second annual survey was carried out during December 2003 to November 2004 inclusive and represents a snapshot of the recreational fishery covering a period of 1.5 to 2.5 years after the area was made a Recreational Fishing Haven.

3.2. Description of study area and access points to the fishery

Tuross Lake (36^{0}03'S 150^{0}07'E) is a wave-dominated barrier estuary (Roy *et al.* 2001) situated on the south coast of New South Wales (Fig. 1). The Tuross Lake estuary is connected to the ocean by a permanently-open channel located near the township of Tuross Head. This small channel restricts tidal flow and the tidal range within the estuary is much smaller (<1m) than that of the adjacent ocean (Roy and Peat 1976). The Tuross Lake estuary consists of a complex series of shallow (1-4m), interconnected channels and lakes, with some deeper areas (about 10m) located in the lower reaches of the estuary (Roy and Peat 1976). The Tuross Lake estuary has a surface area of about 13.3 km^2, a total catchment area of about 1816 km^2 and contains approximately 0.6 km^2 of mangroves, approximately 0.5 km^2 of seagrass and approximately 0.4 km^2 of saltmarsh vegetation (Roy *et al*. 2001).

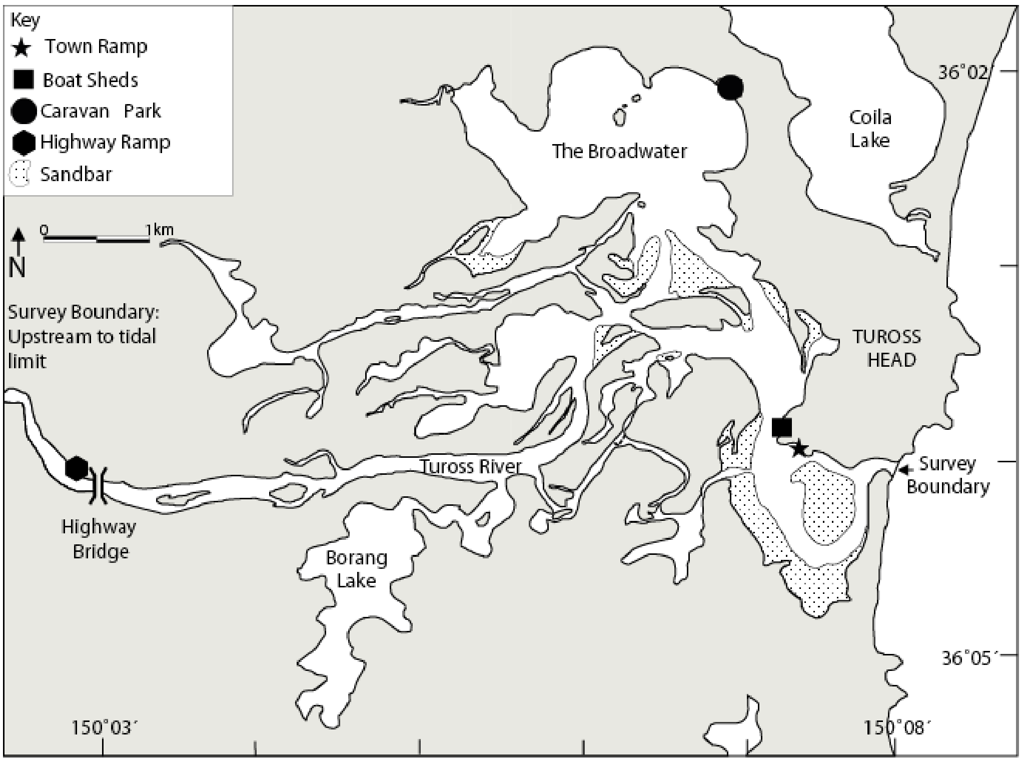

Figure 1. Map of Tuross Lake estuary.

Table 1. Sample sizes for survey data at each access point and for each survey year.

SURVEY YEAR 1				NUMBER OF INTERVIEWS							
Season/Year	Day-Type	No. Days in Stratum	Survey Days	Town Ramp	Hires at Boat Sheds	Non-Hires at Boat Sheds	Caravan Park	Highway Ramp	Total Interviews	No. Refusals	Refusal Rate (%)
Autumn 1999	Weekday	63	6	34	6	5	27	n/a	72	-	-
	Weekend	29	5	58	13	7	45	n/a	123	-	-
	Total	**92**	**11**	**92**	**19**	**12**	**72**	n/a	**195**	-	-
Winter 1999	Weekday	65	5	13	2	0	5	n/a	20	-	-
	Weekend	27	5	49	9	2	17	n/a	77	-	-
	Total	**92**	**10**	**62**	**11**	**2**	**22**	n/a	**97**	-	-
Spring 1999	Weekday	64	7	47	2	2	23	n/a	75	1	1.3
	Weekend	27	6	52	9	4	23	n/a	88	-	-
	Total	**91**	**13**	**99**	**11**	**6**	**46**	n/a	**163**	**1**	0.6
Summer 1999/2000	Weekday	60	8	139	15	5	56	n/a	216	1	0.5
	Weekend	31	8	120	11	3	82	n/a	216	-	-
	Total	**91**	**16**	**259**	**26**	**8**	**138**	n/a	**432**	**1**	0.2
Annual Total	**Weekday**	**252**	**26**	**234**	**25**	**12**	**111**	**n/a**	**383**	**1**	**0.3**
	Weekend	**114**	**24**	**278**	**42**	**16**	**167**	**n/a**	**504**	**1**	**0.2**
	Total	**366**	**50**	**512**	**67**	**28**	**278**	**n/a**	**887**	**2**	**0.2**
SURVEY YEAR 2											
Summer 2003/2004	Weekday	61	9	217	n/a	n/a	86	27	330	1	0.3
	Weekend	30	9	274	n/a	n/a	85	38	397	-	-
	Total	**91**	**18**	**491**	n/a	n/a	**171**	**65**	727	**1**	0.1
Autumn 2004	Weekday	63	9	107	n/a	n/a	52	19	178	1	0.6
	Weekend	29	9	191	n/a	n/a	68	38	297	1	0.3
	Total	**92**	**18**	**298**	n/a	n/a	**120**	**57**	475	**2**	0.4
Winter 2004	Weekday	65	9	45	n/a	n/a	7	10	62	1	1.6
	Weekend	27	9	72	n/a	n/a	12	19	103	-	-
	Total	**92**	**18**	**117**	n/a	n/a	**19**	**29**	165	**1**	0.6
Spring 2004	Weekday	64	9	67	n/a	n/a	46	21	134	-	-
	Weekend	27	9	216	n/a	n/a	52	40	308	1	0.3
	Total	**92**	**18**	**283**	n/a	n/a	**98**	**61**	442	**1**	0.2
Annual Total	**Weekday**	**253**	**36**	**436**	**n/a**	**n/a**	**191**	**77**	**704**	**3**	**0.4**
	Weekend	**113**	**36**	**753**	**n/a**	**n/a**	**217**	**135**	**1105**	**2**	**0.2**
	Total	**366**	**72**	**1189**	**n/a**	**n/a**	**408**	**212**	**1809**	**5**	**0.3**

The fisheries resources within the Tuross Lake estuary were mainly accessible to recreational fishers from boats. Boat-based fishers were able to access the recreational fishery from four access points spread throughout the Lake (Fig. 1). The main public boat ramp (Fig. 1) was the major access point for local residents and for many holiday-makers. A large parking area (about 25-30 spaces), jetty and fish-cleaning facilities were provided at this site. Two businesses (MacKenzie's and Laing's) that hired boats were located alongside each other and were treated as a single access point (Fig. 1). MacKenzie's business offered motor boats, canoes, and sail boats for hire during the day. MacKenzies' premises were also used as a boat storage facility by some local people (about 10-12 berths) during the first survey year but not during the second survey year when ownership of this business had changed (N.B. these premises were renamed O'Brien's boatshed). Laing's business offered motor boats for hire during the day. A caravan park was located on the northern foreshore near the middle of the Lake (Fig. 1). This caravan park had a long, narrow beach frontage that was used by caravan park residents to moor their boats. The caravan park had its own small boat ramp. The use of the boat ramp and beach frontage was restricted to the clientele of the caravan park. A small public boat ramp was located on the western side of the Princes Highway road bridge (Fig. 1). Limited parking (about 3-4 spaces) was available at this site. There were very few boat moorings and private jetties located on the edge of the Lake from which small boats could be launched. Shoreline access to the recreational fishery was minimal because there were large areas of densely vegetated shoreline, and large rural/private properties that precluded public access to the shoreline.

3.3. Survey design

Recreational stakeholders were consulted during the planning phase of the initial survey. These discussions with stakeholders identified the presence of large areas of inaccessible shoreline in the estuary and demonstrated the relatively small size of the shore-based fishery. Consequently, it was agreed that the scope of the survey work would be restricted solely to an assessment of the boat-based fishery. The same on-site, survey design (see Pollock *et al.* 1994 for a review of angler survey methods and terminology) was used to assess the boat-based recreational fishery prior to and after the implementation of the Recreational Fishing Haven in the Tuross Lake estuary, however, the level of daily replication was greater in the second survey period (see Table 1). The boat-based fishery was assessed by using an access(effort)-access(harvest) design combination. Stratified random sampling methods were used with days being the primary sampling unit for all strata. By definition, a survey day started at sunrise and ended at sunset.

3.3.1. Spatial and temporal sampling frames and stratification

The spatial sampling frame (geographical boundary) of the two recreational fishing surveys (Fig. 1) includes the entire Lake area from the ocean to the upstream limit of tidal movement (about 9 km upstream of the highway bridge). The temporal sampling frame of each survey spanned a one year period. Each survey year was stratified into seasons and day-types within season (Weekdays and Weekend days). Public holidays were classified as weekend days. The sequence of seasonal sampling differed between survey years. Survey work done during the first survey year covered Autumn, Winter, Spring, and then Summer, whereas, the sequence of surveying during the second survey year was Summer, Autumn, Winter and then Spring. This difference in the sequence of seasonal sampling is important when considering seasonal comparisons between survey periods because the Summer season comparisons are based on a four year difference whilst the Autumn, Spring and Winter seasonal comparisons are based on a five year difference between sampling periods.

3.4. Data collection methods

Two types of data were collected during this work: (a) survey data that were based on observation and direct contact with boating parties; and (b) auxiliary data that were based on records that quantified boat movements for which the trip activity was unknown.

3.4.1. Survey data

These survey data were derived from direct contact with boating parties at the four access points on scheduled survey days (see Table 2). Two basic types of survey data were collected directly by survey personnel: (a) boat counts and trip activity information for assessing recreational fishing effort and other types of recreational usage; and (b) interview information from recreational fishing parties to assess harvest rates and harvest for the Tuross Lake estuary (see Table 2). The level of daily replication achieved during survey years 1 and 2 respectively represents annual sampling fractions of about 21% and 32% for the weekend day-type stratum and about 10% and 14% for the weekday stratum (Table 1). An independent contractor was employed to ensure that the survey work was carried out in accordance with a pre-scheduled survey roster and to assist with the training and co-ordination of a large group of local volunteers. All survey data were collected by the large group of trained volunteers and the independent contractor. This arrangement ensured that the work was carried out in an efficient and unbiased manner.

3.4.1.1. Boat counts and patterns of recreational usage

The highest priority was placed on collecting accurate and complete counts of recreational boating effort that quantified the number of completed trips (estuary fishing and estuary non-fishing) and the activities of the boating parties. At busy times, accurate effort and trip activity data were collected in preference to interviewing fishing parties for harvest rate and harvest data. Therefore, on scheduled survey days, all boat parties using the four access points were counted, and the party members were asked about their recreational activities (estuary fishing and non-fishing) and the areas of the Lake that they used for recreational purposes (Table 1). Whenever boating parties could not be questioned directly an observation of their fishing gear (or lack of gear) was used to assign the party into either an estuarine fishing category or a non-fishing category. We defined estuarine recreational fishing as all forms of angling within the survey area and included the use of crab nets. We also asked about other recreational activities, such as, offshore fishing outside the estuary, bait collecting, picnicing and swimming, sightseeing, and we included a generalist category to incorporate other types of recreational boating activities such as sailing, water skiing and jet skiing. All boat count and recreational activity information was recorded on machine-readable forms.

3.4.1.2. Interviews with recreational fishing parties

Fishing parties were approached and asked to participate in the survey by providing information about their fishing trip and their harvest. Attempts were made to interview all recreational fishing parties encountered, however, during periods of high recreational activity it was necessary to systematically subsample every second or third fishing party (depending on the number of fishing parties available for interview). The number of interviews obtained at each access point are summarised for each day-type within each season for both survey years (Table 1). Refusals to provide information, or to show the fish retained, were also recorded (Table 1). We asked co-operative recreational fishers about their targeting preferences during their current fishing trip, the time they started fishing and their fishing locations. We also recorded the number of fishers in the fishing party (non-fishers were not included as part of a fishing party). The retained catch was

Table 2. Comparison of data collection methods used at each access point during the two survey years.

	SURVEY YEAR 1 (March 1999 to February 2000)				SURVEY YEAR 2 (December 2003 to November 2004)			
	SURVEY DATA		AUXILIARY DATA		SURVEY DATA		AUXILIARY DATA	
ACCESS POINTS	a) Boat Counts & Activities	b) Interviews	a) Automated Traffic Records	b) Boat-Hire Records	a) Boat Counts & Activities	b) Interviews	a) Automated Traffic Records	b) Boat-Hire Records
Town Ramp	Yes	Yes	Yes	N/A	Yes	Yes	Yes	N/A
Boat Sheds	Yes (hire & non-hire boats)	Yes (hire & non-hire boats)	N/A	Yes	Yes (hire only)*	No	N/A	No
Caravan Park	Yes	Yes	N/A	N/A	Yes	Yes	N/A	N/A
Highway Ramp	No	No	Yes #	N/A	Yes	Yes	Yes	N/A

* Non-hire boats not stored at shed during this survey period

data for Winter, Spring and Summer only

identified by field staff and, whenever possible, measurements of all fish (fork length), crabs (carapace length) and squid (mantle length) were taken to the nearest whole centimetre. When fishers were in a hurry to leave the ramp and it was not possible to measure all fish, crabs and squid, the survey personnel were instructed to record counts of the identified harvest and attempt to measure a sub-sample of the harvest. Machine-readable interview forms were used to record the information from interviews.

3.4.2. Auxiliary data

Auxiliary data were also collected and used to improve the temporal coverage of the fishery. Two separate auxiliary datasets were used during this study: (a) automated traffic records from the main public boat ramp and the smaller boat ramp near the highway bridge; and (b) boat-hire records from Mackenzie's and Lacings boat sheds. These auxiliary datasets provided information about boating trips for which the trip activity was unknown.

3.4.2.1. Automated traffic records from boat ramps

The automated ramp traffic system consisted of a weatherproof box which was securely chained to a fixed structure, such as a telegraph pole, adjacent to the position of deployment. The box housed a battery and a computer that was used to receive, process and store the records of traffic movements. A 'road-tube' sensor was connected to the computer and fixed in position across the lane of the boat ramp. In theory, a count should have been recorded in the computer's memory each time an axle passed over the road-tube sensor. The Eurobodalla Shire Council provided two automated traffic recorders to assess the level of usage at the main ramp and the highway ramp (see Fig. 1) during the Winter, Spring and Summer seasons of the first survey year. New automated traffic recorders were purchased and used during the second survey year. The calibration of the automated counters used was different between years. The counters provided by the council during the first survey year were programmed to record the ramp traffic movements as a series of 24 separate 'hourly counts' for each date. In contrast, the counters used during the second survey year recorded data in separate blocks of five minutes duration for each date.

Count data were assigned into daytime and night-time categories to facilitate the estimation of daytime recreational fishing effort. In the first survey year the 'daytime period' was defined as that block of hourly counts starting from the hourly count preceding sunrise and ending with the hourly count following sunset. In the second survey year the 'daytime period' was defined as that time period starting from the count containing sunrise and ending with the count containing sunset. Therefore, in both survey years the 'night-time period' was defined as those counts not included in the 'daytime period'.

3.4.2.2. Boat-hire records

The proprietors of Mackenzie's and Laing's boat-hire businesses provided us with access to their boat-hire records for the period of the first survey year on the condition that these records be treated with the strictest confidence. That is, to maintain the confidentiality of these boat-hire records the estimates of fishing effort generated from them are reported as part of a combined estimate for the entire Tuross Lake fishery. These daily boat-hire records covering the entire first survey year represent a census (complete enumeration) of the hire-boat trips made from this access point. This dataset did not provide information about trip activities. These comprehensive boat-hire records were not available for the second survey year.

3.5. Estimation methods

The following sections provide brief explanations of the estimation methods used to calculate: (a) fishing effort; (b) harvest rates; and (c) harvest. Detailed explanations of the statistical procedures used can be found in Cochran (1953), Robson (1960), Yates (1965), Sokal and Rohlf (1969); Malvestuto (1983), Hayne (1991), and Pollock *et al*. (1994 & 1997).

3.5.1. Effort estimation

Recreational fishing effort was estimated separately for each access site during each survey year. Table 3 gives a brief summary of the effort estimation methods used for each access site during each survey year. The types of data available for effort estimation at an access site were sometimes different between survey years (Table 2) thereby leading to the use of different estimation methods at the same access site between survey years. The basic methods used to estimate recreational fishing effort were: (a) summation of survey data within a base level stratum (day-type within season) to provide a measure of effort on those survey days; (b) direct expansion of the sample data (e.g. survey data or automated traffic record data); (c) regression methods when auxiliary data were used to supplement survey data; and (d) data imputation when no data were available within a base level stratum. A brief description of these methods is given in the following sections.

Estimates of boat-based recreational effort for the entire estuarine fishery in Tuross Lake are provided in units of boat trips and fisher hours to facilitate comparisons with other studies. The base level of effort estimation was a day-type stratum within a season at each access site. Whole fishery estimates for each day-type stratum were obtained by adding the estimates from the access sites. Then seasonal estimates of effort were obtained by adding the estimates from the day-type strata together. Annual estimates of effort were made by adding seasonal estimates. Whenever strata were combined their variances were additive.

Table 3. Summary of effort estimation methods used at each access point during the two survey years.

ACCESS POINTS	SURVEY YEAR 1 (March 1999 to February 2000)	SURVEY YEAR 2 (December 2003 to November 2004)
Town ramp	Summation & expansion of survey data PLUS regression methods	Summation of survey data PLUS regression methods
Boat sheds:		
a) Hire-boats	Summation of survey data PLUS regression methods	Summation & expansion of survey data
b) Non-hire boats	Summation & expansion of survey data	N/A
Caravan park	Summation & expansion of survey data	Summation & expansion of survey data
Highway ramp	Data Imputation (Autumn only) Expansion of auxiliary data PLUS regression methods (Winter, Spring & Summer)	Summation of survey data PLUS regression methods

3.5.1.1. Summation of survey data

This refers to the addition of the daily effort totals observed on scheduled survey days. The survey data were regarded as accurate measures of validated effort so the addition of these data represents an accurate measure of effort on those scheduled survey days. This was done whenever survey data were available.

3.5.1.2. Direct expansion of sample data

This method simply provides an estimate of the unsampled fraction of a stratum by expansion from the available sample data. General equations used for the direct expansion of survey and auxiliary data and their associated variances are provided by Pollock *et al*. (1994).

3.5.1.3. Interpretation and validation of auxiliary data using regression methods

a) Automated ramp traffic records

The automated ramp traffic data at a boat ramp are counts of pulses detected by the road-tube sensor and logged in the computer memory. These counts are presumed to correspond to the number of axles that have passed over the road-tube sensor in any direction but, in reality, are variable because of differences in sensor sensitivity/calibration and changing levels of background 'noise'. Interpretation of these counts requires validation of the relationship between the counts (an estimate measured with error) and the total number of trips (a measurement without error of the true value). We used rostered survey days that coincided with the collection of automated ramp traffic data to calculate a correction factor (with variance) to convert the traffic record data from 'clicks' into units of boat trips. This was done separately for the main ramp and the highway ramp on each survey year by fitting a linear regression that was forced through the origin to the daily replicate data that was pooled across all strata within that year. The independent variate (x axis) was the number of completed boat trips recorded by the field staff on designated survey days and the dependent variable (y axis) was the daytime number of 'clicks' recorded by the traffic counter. The regression equations used and their summary statistics for each boat ramp and each survey year are provided in Table 4. Plots of residuals indicated that the correct models had been fitted and that the assumptions of the analyses were met.

A similar regression approach was used to then convert the data from numbers of boat trips (activity unknown) into numbers of recreational fishing trips. Replicate daily survey data were pooled across all strata within each survey year for each public boat ramp and then analysed with linear regression that was forced through the origin. The independent variate (x axis) was the total number of trips observed on a survey day at a ramp and the independent variable (y axis) was the number of recreational fishing trips recorded on the corresponding days. The regression equations used and their summary statistics for each boat ramp and each survey year are provided in Table 4. Plots of residuals indicated that the correct models had been fitted and that the assumptions of the analyses were met. Thus, the regression coefficients from these analyses (denoted as b_1) provided estimates of the daily proportion of estuarine recreational fishing trips.

The estimation of trips involved in 'other activities' (i.e. all trips that did not include the activity of estuarine recreational fishing) was derived from the same regression analyses. The estimates of the daily proportion of 'other activity' trips (denoted as b_2) were calculated as $b_2 = 1 - b_1$ according to the binomial distribution theory (Cochran 1953). Thus, the variance of each pair of regression coefficients is identical (Cochran 1953).

Table 4. Regression equations and their associated summary statistics. These equations used validated survey data to convert auxiliary data into compatible units of effort.

ACCESS POINTS	REGRESSION EQUATIONS	SUMMARY STATISTICS
Town Ramp (Year 1)	Traffic Record Clicks = 6.3580 Trips (activity unknown)	Adj $R^2 = 0.813$ d.f. = 1,32 $p<0.001$
Town Ramp (Year 1)	Estuary Fishing Trips = 0.8657 Trips (activity unknown)	Adj $R^2 = 0.947$ d.f. = 1,32 $p<0.001$
Boat Sheds (Year 1)	Estuary Fishing Trips (hire-boats) = 0.8155 Trips (hire-boats activity unknown)	Adj $R^2 = 0.879$ d.f. = 1,35 $p<0.001$
Town Ramp (Year 2)	Traffic Record Clicks = 24.7374 Trips (activity unknown)	Adj $R^2 = 0.895$ d.f. = 1,71 $p<0.001$
Town Ramp (Year 2)	Estuary Fishing Trips = 0.9536 Trips (activity unknown)	Adj $R^2 = 0.981$ d.f. = 1,71 $p<0.001$
Highway Ramp (Year 2)	Traffic Record Clicks = 26.8183 Trips (activity unknown)	Adj $R^2 = 0.686$ d.f. = 1,71 $p<0.001$
Highway Ramp (Year 2)	Estuary Fishing Trips = 0.7948 Trips (activity unknown)	Adj $R^2 = 0.870$ d.f. = 1,35 $p<0.001$

Note: Town ramp (Year 1) equations used for Highway Ramp (Year 1)

During the first survey year, the automated traffic recorder equipment was vandalised occasionally and this caused gaps in the available dataset. These data gaps were addressed by direct expansion of raw click data prior to the use of regression methods. The automated traffic records were collected at the highway ramp during the Winter, Spring and Summer seasons of the first survey year but no survey data were collected at this access point during this period (Table 2). In this case, we applied the regression coefficients (and associated variances) derived from the main ramp to estimate recreational fishing effort at this access point.

b) Boat-hire records

The boat-hire records available during the first survey year provided a census of hire-boat trips originating from the boat sheds. The activity undertaken during these boat trips were unknown. A regression approach was used to convert these data into numbers of estuarine recreational fishing trips and numbers of non-fishing trips. Replicate daily survey data collected at this access point was pooled across all strata in the survey year. The same regression procedures outlined above were used and summary statistics of these analyses are provided in Table 4. Plots of residuals indicated that the correct models had been fitted and that the assumptions of the analyses were met. Thus, the regression coefficients from these analyses provided estimates of the daily proportion of estuarine recreational fishing trips at this access point.

3.5.1.4. Data imputation

A data imputation method was used to estimate recreational fishing effort at the highway ramp for Autumn of the first survey year. This was done separately for each day-type stratum in this season. A contingency table containing recreational fishing data and having access sites as rows and seasons as columns was constructed for each day-type stratum. A starting value of zero was fitted to the missing cell of the contingency table. Chi-square values were calculated for each table cell and then for the entire table. The Solver program in Excel was used to iteratively fit effort values into the contingency table and recalculate Chi-square values until a solution was found which minimised the overall table Chi-square value. This solution provided an imputed estimate of recreational fishing effort based on other survey data. Additional variance was proportionally allocated to this effort estimate according to its size relative to total annual effort in the fishery.

3.5.2. Harvest rate estimation

Boat-based fishing parties were approached at the access points when they returned from their fishing trip. The harvest rate information collected during these access point interviews is based on completed trips (Malvestuto 1983, Hayne 1991, Pollock *et al*. 1994, Pollock *et al*. 1994 & 1997). When the objective is to estimate total harvest, and the interview data are derived from completed trips, the correct harvest rate estimator to use is the ‘ratio of means’ (Jones *et al*. 1995, Pollock *et al*. 1997). This estimator is essentially the ratio of mean harvest to mean effort on a given day. The mean daily ‘ratio of means’ estimator calculated for each base stratum was used for estimating the harvest of the boat-based fishery.

Seasonal harvest rates were calculated by combining estimates derived from day-type strata within each season. The contribution of each day-type stratum to the estimated seasonal harvest rate was weighted by the relative size of each day-type stratum within the season (Pollock *et al*. 1994). This means that a greater weighting was given to the weekday stratum because there are more weekdays in a month than there are weekend days in a month.

3.5.3. Harvest estimation

Recreational harvest was estimated separately for each access point during each survey year. Table 5 gives a brief summary of the harvest estimation methods used. The types of data available for harvest estimation at an access point were sometimes different between survey years (Table 2) thereby leading to the use of different estimation methods at the same access point between survey years. The basic methods used to estimate recreational harvest at an access point were: (a) summation and expansion of interview data within a base level stratum (day-type within season); and (b) the product of boat-based effort and a harvest rate (an appropriate mean daily 'ratio of means' harvest rate – see Table 5). Pollock *et al.* (1994) provide detailed descriptions of these estimation methods and the calculation of variances. The summation and expansion of interview data was used when auxiliary datasets were not available. The product of effort and harvest rate was used whenever auxiliary data were used to supplement survey datasets or when pooled harvest rate data from multiple access points were needed to obtain harvest estimates at another access point.

Table 5. Summary of harvest estimation methods used at each access point during the two survey years.

ACCESS POINTS	SURVEY YEAR 1 (March 1999 to February 2000)	SURVEY YEAR 2 (December 2003 to November 2004)
Town ramp	Harvest = effort x harvest rate $_1$	Harvest = effort x harvest rate $_4$
Boat sheds:		
a) Hire-boats	Harvest = effort x harvest rate $_2$	Harvest = effort x harvest rate $_5$
b) Non-hire boats	Harvest = effort x harvest rate $_1$	N/A
Caravan park	Summation & expansion of caravan park interview data	Summation & expansion of caravan park interview data
Highway ramp	Harvest = effort x harvest rate $_3$	Harvest = effort x harvest rate $_6$

Key:

1 - derived from pooling interview data from town ramp and non-hire boats at boat sheds

2 - derived from pooling interview data for hire-boats at boat sheds

3 - derived from pooling interview data (Year 1) from all other access points

4 - derived from interview data from town ramp

5 - derived from pooling interview data (Year 2) from all other access points

6 - derived from interview data from highway ramp

Estimates of boat-based recreational harvest for the entire estuarine fishery in Tuross Lake are provided in terms of fish numbers and weight. The base level of harvest estimation was a day-type stratum within a season at each access point. Whole fishery estimates for each day-type stratum were obtained by adding the estimates from the access points. Then seasonal estimates of harvest were obtained by adding the estimates from the day-type strata together. Annual harvest estimates were made by adding the seasonal estimates together. Whenever strata were combined their variances were additive.

We did not attempt to make expanded estimates of harvest for any taxon that was considered to have been 'rare' throughout the survey period - defined as any taxon that had been recorded from two or less interviews during a survey year, regardless of the number of individuals harvested in those trips. This definition of rarity was applied separately during each survey year. All taxa which did not meet the criterion for rarity were classified as common taxa and expanded estimates of harvest were made for these taxa.

We converted the length measurements of fish, squid and crabs taken during interviews into weights using length to weight keys (Appendix 1). The remaining unmeasured component of the harvest (i.e. those fish seen during interviews but only counted) were assigned the median weight for that taxon as calculated from the pooled interview data for each season within a survey year. We used a median weight rather than a mean weight (as is traditionally done in angler surveys) because many of the estimated weight frequency distributions were highly skewed, making the median a better estimate of the centre of the population (Sokal and Rohlf 1969). In some cases, the use of a mean would have resulted in higher estimates of harvest. In some cases, measurements were not available for some taxa and so we could not estimate weights.

3.6. Statistical comparisons between survey periods

Annual estimates of recreational fishing effort and harvest for the whole boat-based fishery in Tuross Lake and seasonal estimates of harvest rates have been made for each survey period. We have presented 95% confidence limits for each of these estimated values. The 95% confidence limits provide information about the plausible range that contains the true value of the parameter that has been estimated. Thus, when comparing any two estimates of interest it is important to determine whether the confidence intervals overlap. When the confidence intervals overlap we cannot be 95% certain that the two estimates being compared are different. Thus, we conclude that in this case there is no statistically significant difference between the two estimates ($p>0.05$). Conversely, when the confidence intervals do not overlap we can be 95% certain that the two estimates are different. Thus, we can conclude that a statistically significant difference exists ($p<0.05$) between the two estimates.

Recreational fishing effort comparisons between survey years are made in units of boat trips, boat hours and fisher hours. The presentation of fishing effort estimates in three different units is intended to facilitate comparisons with other studies which may report effort estimates in only one type of unit.

Harvest comparisons between survey years were not made for any species/taxon that was not recorded or was assigned a 'rare' status during one or both survey years. Harvest comparisons between survey years, by number and weight, are presented for all other species (see Tables 7 & 8) to allow a comprehensive documentation of survey results. However, the discussion of comparisons (by number and weight) between survey years has been restricted to those twelve species that had estimated annual harvests greater than 1.5% of the total harvest (by number) during one or both survey years. This criterion has been used because we believe that harvest comparisons based on smaller annual harvest sizes provide very limited ecological insights. We strongly believe that the detection of some statistically significant differences when comparing low annual harvest estimates between survey years is indicative of high precision in the survey data (a result of good survey design and high levels of sampling intensity) rather than meaningful ecological changes in the fishery.

3.7. Indicators of recreational fishing quality

An assessment of a recreational fishery can be improved if reliable indicators of fishing quality are available. We present two indicators of recreational fishing quality for the boat-based fishery in Tuross Lake so that comparisons can be made between survey periods. The indicators are: (1) recreational harvest rates for the main species of recreational importance as determined by their relative harvest sizes in each survey year; and (2) size-frequency distributions for these same species. The harvest rates are based on calculations made using total fishing effort (non-directed effort) for a stratum. We present boat-based harvest rates for the entire estuarine fishery and for each season in units of number of fish per fisher hour. The amalgamation of these harvest rate data into larger groupings (e.g. annual harvest rates) were not done for any taxon because they may mask the seasonal trends and do not enhance the assessment of the recreational fishery. Size frequency distributions are presented for the entire fishery during each of the two survey years.

4. RESULTS

4.1. Recreational fishing effort

Recreational fishing effort estimates are provided in units of boat trips, boat hours and fisher hours. We estimated that about 8,200 and 10,300 boat trips were expended in the Tuross Lake fishery during the first and second survey years respectively (Table 6). This represents an overall increase in recreational fishing boat trips of about 25% (significant difference, $p<0.05$) since the first survey (Table 6).

The recreational fishing boat trips represented about 28,800 and 36,700 boat hours of fishing effort during the first and second survey year respectively (Table 6). This represents an overall increase in boat hours of about 27% (significant difference, $p<0.05$) since the first survey (Table 6).

The recreational fishing boat hours represented about 67,500 and 83,600 fisher hours of fishing effort during the first and second survey year respectively (Table 6). This represents an overall increase in fisher hours of about 24% (significant difference, $p<0.05$) since the first survey (Table 6).

4.2. Recreational harvest

We recorded 29 taxa in the retained catch of recreational boat-based fishers during the first survey year and 31 during the second survey year (Table 7, Appendix 2). We estimated that about 26,650 fish, crabs and cephalopods (20,809 to 32,499 individuals - approximate 95% Confidence Limits) were harvested by daytime, boat-based, recreational fishers from the Tuross Lake estuary during the first survey year and about 27,830 fish, crabs and cephalopods (25,543 to 30,123 individuals - approximate 95% Confidence Limits) were harvested during the second survey year (Table 7). In both survey years the recreational harvest was dominated by relatively few taxa (Table 7). The twelve species which met the criterion of having annual harvest estimates greater than 1.5% of the total harvest (by number) during one or both survey years accounted for 96.7% and 96.0% of the daytime recreational harvest (by number) during the first and second survey years respectively (Table 7). However, the relative contribution of these dominant taxa changed markedly between survey years (Table 7). For example, the total harvest (by number) of dusky flathead, yellowfin bream and sand whiting increased significantly since the first survey period (Table 7). In contrast, the total harvest (by number) of luderick, large-toothed flounder, yelloweye mullet and small-toothed flounder decreased significantly since the first survey period (Table 7). Changes in total harvest (increases or decreases) were also observed for river garfish, sand mullet, tailor, sea garfish and yellow-finned leatherjacket but these observed changes were not statistically different ($p>0.05$) between the survey periods (Table 7).

We estimated that about 8.7 tonnes of fish, crabs and cephalopods (7.1 to 10.3 tonnes - approximate 95% Confidence Limits) were harvested by daytime, boat-based, recreational fishers from the Tuross Lake estuary during the first survey year and about 12.4 tonnes of fish, crabs and cephalopods (11.3 to 13.4 tonnes - approximate 95% Confidence Limits) were harvested during the second survey year (Table 8). In both survey years the recreational harvest was dominated by relatively few taxa (Table 8). The twelve species which met the criterion of having annual harvest estimates greater than 1.5% of the total harvest (by number) during one or both survey years accounted for 96.4% and 95.2% of the daytime recreational harvest (by weight) during the first and second survey years respectively (Table 8). However, the relative contribution of these dominant taxa changed markedly between survey years (Table 8). For example, the total harvest (by weight) of dusky flathead, sand whiting and sand mullet increased significantly since the first survey period (Table 8). In contrast, the total harvest (by weight) of luderick, large-toothed flounder, yelloweye mullet and small-toothed flounder decreased significantly since the first survey period (Table 8). Changes in total harvest (increases or decreases) were also observed for yellowfin bream, river garfish, tailor, sea garfish and yellow-finned leatherjacket but these observed changes were not statistically different ($p>0.05$) between the survey periods (Table 8).

Table 6. Estimates of daytime recreational fishing effort (boat trips, boat hours and fisher hours) and 95% confidence intervals for the boat-based fishery in the Tuross Lake estuary for each survey year. The proportional changes between survey years and their statistical significance are presented.

	SURVEY YEAR 1 (March 1999 to February 2000)		SURVEY YEAR 2 (December 2003 to November 2004)		COMPARISON BETWEEN SURVEY YEARS	
Fishing Effort	Effort	95% Confidence Intervals	Effort	95% Confidence Intervals	% Change	Statistical Significance
Boat Trips	**8,229**	**7,410 to 9,048**	**10,306**	**9,762 to 10,850**	**25.2%**	*
Boat Hours	**28,813**	**25,845 to 31,781**	**36,697**	**34,837 to 38,557**	**27.4%**	*
Fisher Hours	**67,469**	**60,405 to 74,532**	**83,626**	**78,542 to 88,709**	**23.9%**	*

* Significantly different, $p < 0.05$.

Table 7. Annual harvest estimates (number of individuals) and 95% confidence intervals for taxa taken by boat-based recreational fishers in the Tuross Lake estuary for each survey year. The proportional changes between survey years and their statistical significance are presented.

COMMON NAME	SURVEY YEAR 1 (March 1999 to February 2000)			SURVEY YEAR 2 (December 2003 to November 2004)			COMPARISON BETWEEN SURVEY YEARS	
	Total Fish (number)	95% Confidence Intervals	% Total	Total Fish (number)	95% Confidence Intervals	% Total	% Change (number)	Statistical Significance
Dusky Flathead	7,776	6,423 to 9,129	29.2%	13,780	12,084 to 15,476	49.5%	77.2%	*
Yellowfin Bream	1,929	1,132 to 2,726	7.2%	4,096	3,390 to 4,802	14.7%	112.3%	*
Sand Whiting	385	146 to 624	1.4%	3,599	2,845 to 4,353	12.9%	834.8%	*
River Garfish	1,849	837 to 2,861	6.9%	1,391	591 to 2,191	5.0%	-24.8%	ns
Sand Mullet	449	16 to 882	1.7%	1,346	877 to 1,815	4.8%	199.8%	ns
Luderick	2,802	1,678 to 3,926	10.5%	945	538 to 1,352	3.4%	-66.3%	*
Tailor	312	163 to 461	1.2%	464	271 to 657	1.7%	48.7%	ns
Large-Toothed Flounder	1,162	829 to 1,495	4.4%	445	279 to 611	1.6%	-61.7%	*
Sea Garfish	1,071	141 to 2,001	4.0%	278	0 to 603	1.0%	-74.0%	ns
Yelloweye Mullet	5,628	704 to 10,552	21.1%	245	50 to 440	0.9%	-95.6%	*
Blue Swimmer Crab	28	0 to 57	0.1%	199	121 to 277	0.7%	610.7%	*
Silver Trevally	330	193 to 467	1.2%	196	111 to 281	0.7%	-40.6%	ns
Black Bream	35	10 to 60	0.1%	186	81 to 291	0.7%	431.4%	*
Silver Biddy †	-	-	-	143	8 to 278	0.5%	-	-
Snapper	3#	-	<0.1%	127	69 to 185	0.5%	-	-
Small-Toothed Flounder	791	428 to 1,154	3.0%	121	55 to 187	0.4%	-84.7%	*
Australian Salmon	52	3 to 101	0.2%	66	0 to 145	0.2%	26.9%	ns
Mud Crab	-	-	-	62	22 to 102	0.2%	-	-
Red Gurnard	34	0 to 68	0.1%	41	0 to 93	0.1%	20.6%	ns
Octopus †	25	0 to 61	<0.1%	40	0 to 92	0.1%	60.0%	ns
Tarwhine	1#	-	-	18	0 to 43	<0.1%	-	-
Sea Mullet	201	37 to 365	0.8%	16	0 to 39	<0.1%	-92.0%	ns

Table 7 (continued)

COMMON NAME	SURVEY YEAR 1 (March 1999 to February 2000)			SURVEY YEAR 2 (December 2003 to November 2004)			COMPARISON BETWEEN SURVEY YEARS	
	Total Fish (number)	95% Confidence Intervals	% Total	Total Fish (number)	95% Confidence Intervals	% Total	% Change (number)	Statistical Significance
Yellow-Finned Leatherjacket	1,630	0 to 3,561	6.1%	11	0 to 25	<0.1%	-99.3%	ns
Southern Sand Flathead	89	0 to 197	0.3%	1#	-	<0.1%	-	-
Shovelnose Ray †	19	0 to 38	<0.1%	-	-	-	-	-
Six-Spined Leatherjacket	47	0 to 99	0.2%	-	-	-	-	-
Other Taxa^	6	-	<0.1%	17	-	<0.1%	-	-
Grand Total	**26,654**	**20,809 to 32,499**	**100%**	**27,833**	**25,543 to 30,123**	**100%**	**4.4%**	**ns**

Key:
Expanded estimates of harvest have not been calculated. This observation was classified as a rare event during this time period and its occurrence is simply noted.
* Significantly different, $p<0.05$.
ns No significant difference, $p>0.05$
- Not recorded or not calculated for rare event occurrences.
^ Other taxa details are provided in Appendix 2.
† Associated estimates of expanded weight (kg) are not provided for this taxon in Table 8 because a suitable length to weight conversion key was not available

Table 8. Annual harvest estimates (kilograms) and 95% confidence intervals for taxa taken by boat-based recreational fishers in the Tuross Lake estuary for each survey year. The proportional changes between survey years and their statistical significance are presented.

COMMON NAME	SURVEY YEAR 1 (March 1999 to February 2000)			SURVEY YEAR 2 (December 2003 to November 2004)			COMPARISON BETWEEN SURVEY YEARS	
	Total Fish (kgs)	95% Confidence Intervals	% Total	Total Fish (kgs)	95% Confidence Intervals	% Total	% Change (kgs)	Statistical Significance
Dusky Flathead	2,800	2,317 to 3,283	32.1%	6,784	5,919 to 7,649	54.9%	142.3%	*
Yellowfin Bream	1,290	618 to 1,962	14.8%	2,181	1,783 to 2,579	17.7%	69.1%	ns
Sand Whiting	88	35 to 141	1.0%	1,019	811 to 1,227	8.2%	1058.0%	*
Luderick	1,970	1,183 to 2,757	22.6%	666	358 to 974	5.4%	-66.2%	*
Sand Mullet	93	0 to 194	1.1%	488	315 to 661	4.0%	424.7%	*
Tailor	87	44 to 130	1.0%	263	93 to 433	2.1%	202.3%	ns
Blue Swimmer Crab	11	0 to 23	0.1%	134	62 to 206	1.1%	1118.2%	*
Black Bream	24	3 to 45	0.3%	131	51 to 211	1.1%	445.8%	*
Silver Trevally	116	68 to 164	1.3%	127	73 to 181	1.0%	9.5%	ns
Yelloweye Mullet	1,302	278 to 2,326	14.9%	110	22 to 198	0.9%	-91.6%	*
River Garfish	108	43 to 173	1.2%	109	35 to 183	0.9%	0.9%	ns
Large-Toothed Flounder	175	122 to 228	2.0%	81	50 to 112	0.7%	-53.7%	*
Mud Crab	-	-	-	65	25 to 105	0.5%	-	-
Australian Salmon	68	11 to 125	0.8%	62	8 to 116	0.5%	-8.8%	ns
Snapper	<1	-	<0.1%	46	25 to 67	0.4%	-	-
Small-Toothed Flounder	142	78 to 206	1.6%	27	11 to 43	0.2%	-81.0%	*
Sea Mullet	60	13 to 107	0.7%	18	0 to 46	0.1%	-70.0%	ns
Sea Garfish	76	10 to 142	0.9%	15	0 to 34	0.1%	-80.3%	ns
Red Gurnard	7	1 to 13	<0.1%	13	0 to 32	0.1%	85.7%	ns
Tarwhine	<1	-	<0.1%	3	0 to 7	<0.1%	-	-
Yellow-Finned Leatherjacket	275	0 to 585	3.2%	3	0 to 7	<0.1%	-98.9%	ns

Table 8 (continued)

COMMON NAME	SURVEY YEAR 1 (March 1999 to February 2000)			SURVEY YEAR 2 (December 2003 to November 2004)			COMPARISON BETWEEN SURVEY YEARS	
	Total Fish (kgs)	95% Confidence Intervals	% Total	Total Fish (kgs)	95% Confidence Intervals	% Total	% Change (kgs)	Statistical Significance
Six-Spined Leatherjacket	8	0 to 19	<0.1%	-	-	-	-	-
Southern Sand Flathead	21	0 to 47	<0.1%	<1	-	<0.1%	-	-
Other Taxa^	3	-	<0.1%	13	-	0.1%	-	-
Grand Total	**8,725**	**7,148 to 10,302**	**100%**	**12,358**	**11,290 to 13,426**	**100%**	**41.6%**	*

Key:
* Significantly different, p<0.05.
ns No significant difference, p>0.05
\- Not recorded or not calculated for rare event occurrences
^ Other taxa details are provided in Appendix 2

4.3. Indicators of Recreational Fishing Quality

4.3.1. Recreational harvest rates

Seasonal trends are evident in the harvest rate information, however, these data are highly variable which means that estimates of seasonal harvest rates are usually imprecise. Thus, most comparisons of harvest rates among seasons within a survey year or between survey years are not statistically significantly different (see Figs. 2 to 5). A brief description of the seasonal harvest rate data that focuses on statistically detectable differences between survey periods is provided below for the main species of recreational importance.

4.3.1.1. Dusky flathead

There were no statistically significant differences in seasonal harvest rates between survey periods for dusky flathead (Fig. 2a).

4.3.1.2. Yellowfin bream

Seasonal harvest rates observed during Autumn and Summer of the second survey year were significantly greater ($p<0.05$) than those measured during the corresponding seasons during the first survey year (Fig. 2b).

4.3.1.3. Sand whiting

Seasonal harvest rates observed during all four seasons of the second survey year were significantly greater ($p<0.05$) than those measured during the corresponding season in the first survey year (Fig. 2c).

4.3.1.4. River garfish

There were no statistically significant differences in seasonal harvest rates between survey periods for river garfish (Fig. 3a).

4.3.1.5. Sand mullet

The seasonal harvest rate observed during the Winter of the second survey year was significantly greater ($p<0.05$) than that measured during the corresponding season during the first survey year for sand mullet (Fig. 3b).

4.3.1.6. Luderick

There were no statistically significant differences in seasonal harvest rates between survey periods for luderick (Fig. 3c)

4.3.1.7. Tailor

There were no statistically significant differences in seasonal harvest rates between survey periods for tailor (Fig. 4a)

4.3.1.8. Large-toothed flounder

The seasonal harvest rate observed during the Summer of the second survey year was significantly lower ($p<0.05$) than that measured during the corresponding season during the first survey year for large-toothed flounder (Fig. 4b).

4.3.1.9. Sea garfish

There were no statistically significant differences in seasonal harvest rates between survey periods for sea garfish (Fig. 4c).

4.3.1.10. Yelloweye mullet

There were no statistically significant differences in seasonal harvest rates between survey periods for yelloweye mullet (Fig. 5a).

4.3.1.11. Small-toothed flounder

Seasonal harvest rates observed during the Spring and Summer seasons of the second survey year were significantly lower ($p<0.05$) than those measured during the corresponding seasons during the first survey year for small-toothed flounder (Fig. 5b).

4.3.1.12. Yellow-finned leatherjacket

There were no statistically significant differences in seasonal harvest rates between survey periods for yellow-finned leatherjacket (Fig. 5c).

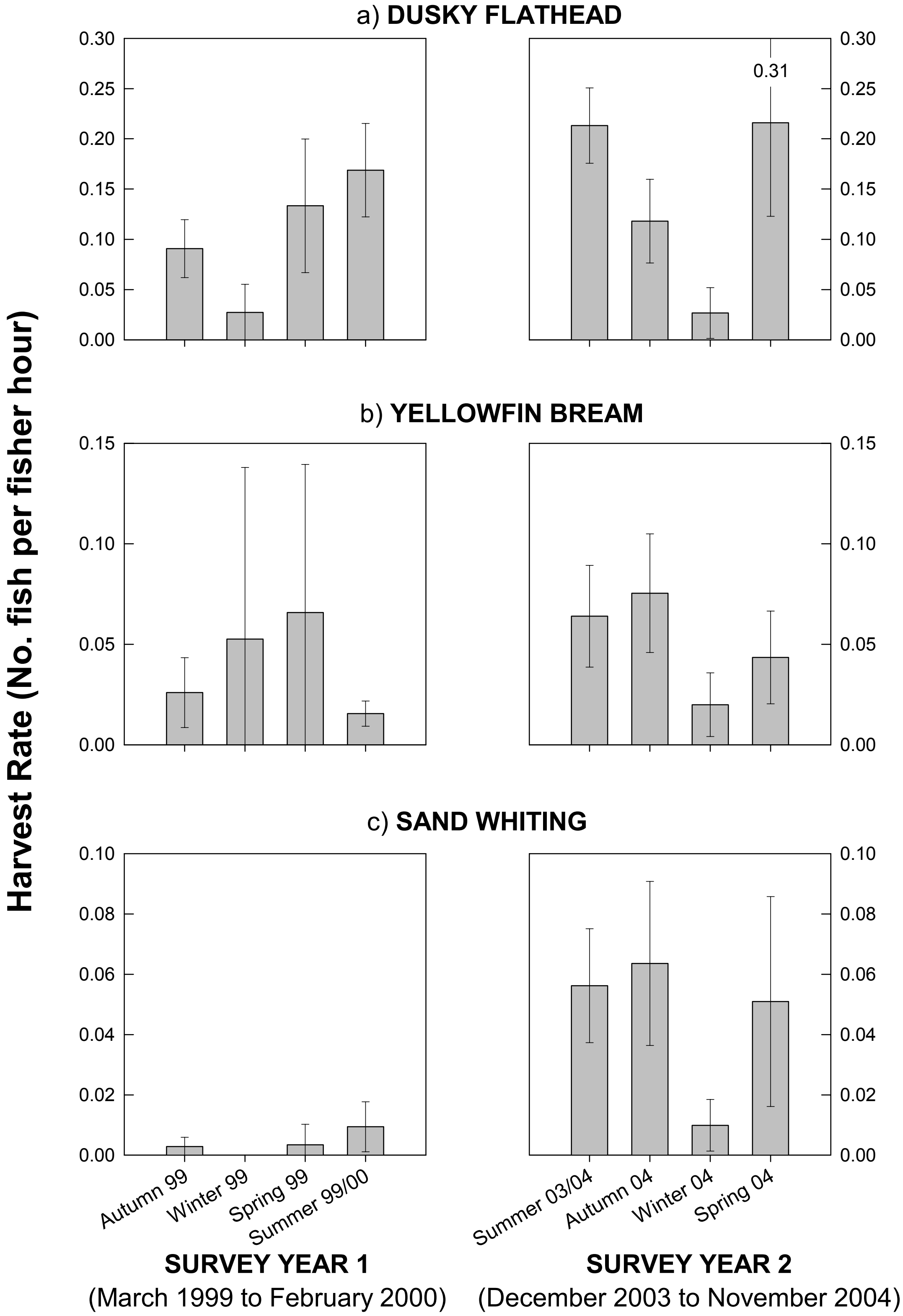

Figure 2. Recreational harvest rate estimates (fish per fisher hour) with 95% confidence intervals for a) dusky flathead, b) yellowfin bream and c) sand whiting taken by recreational fishers in the Tuross Lake boat-based fishery for each survey year.

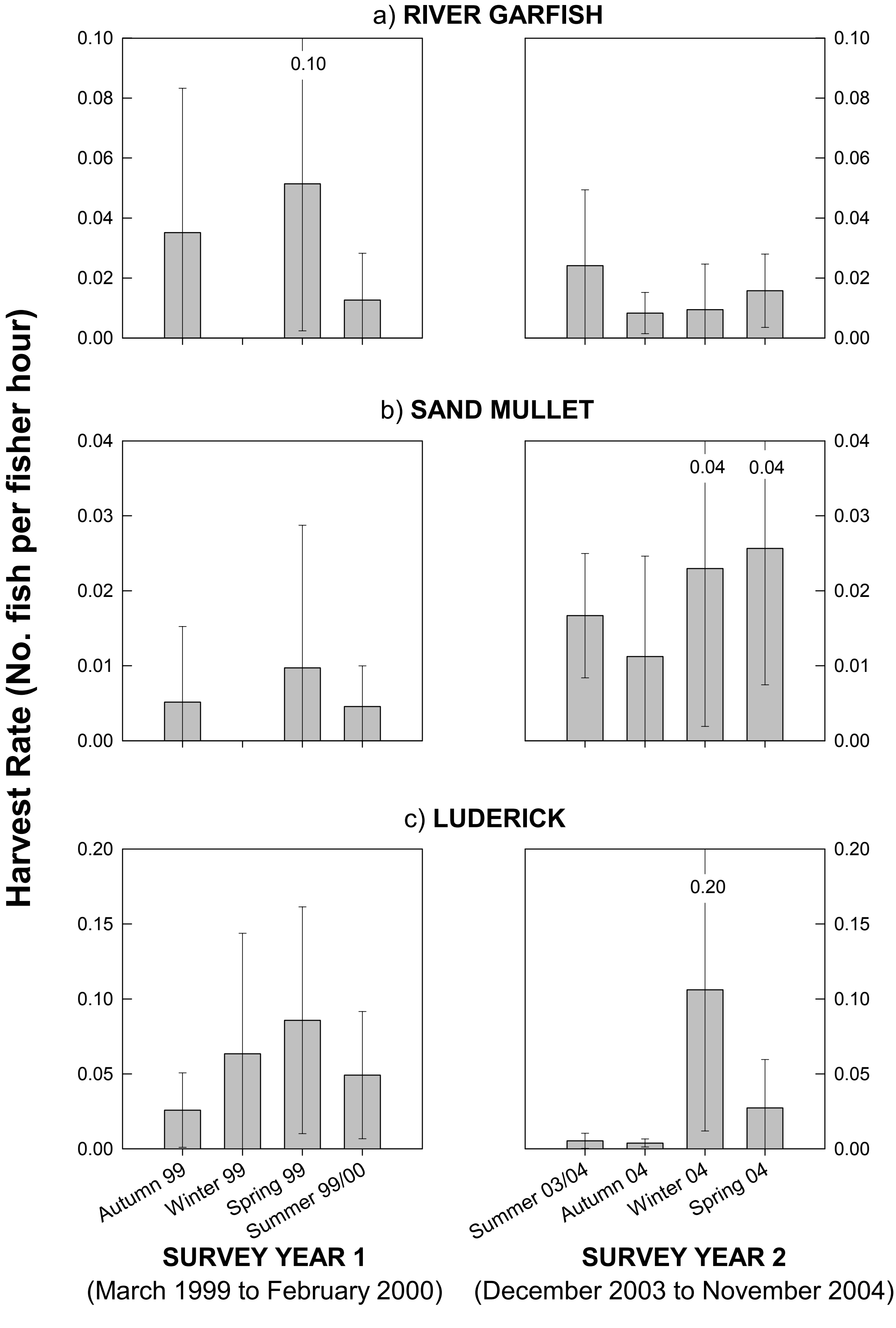

Figure 3. Recreational harvest rate estimates (fish per fisher hour) and 95% confidence intervals for a) river garfish, b) sand mullet and c) luderick taken by recreational fishers in the Tuross lake boat-based fishery for each survey year.

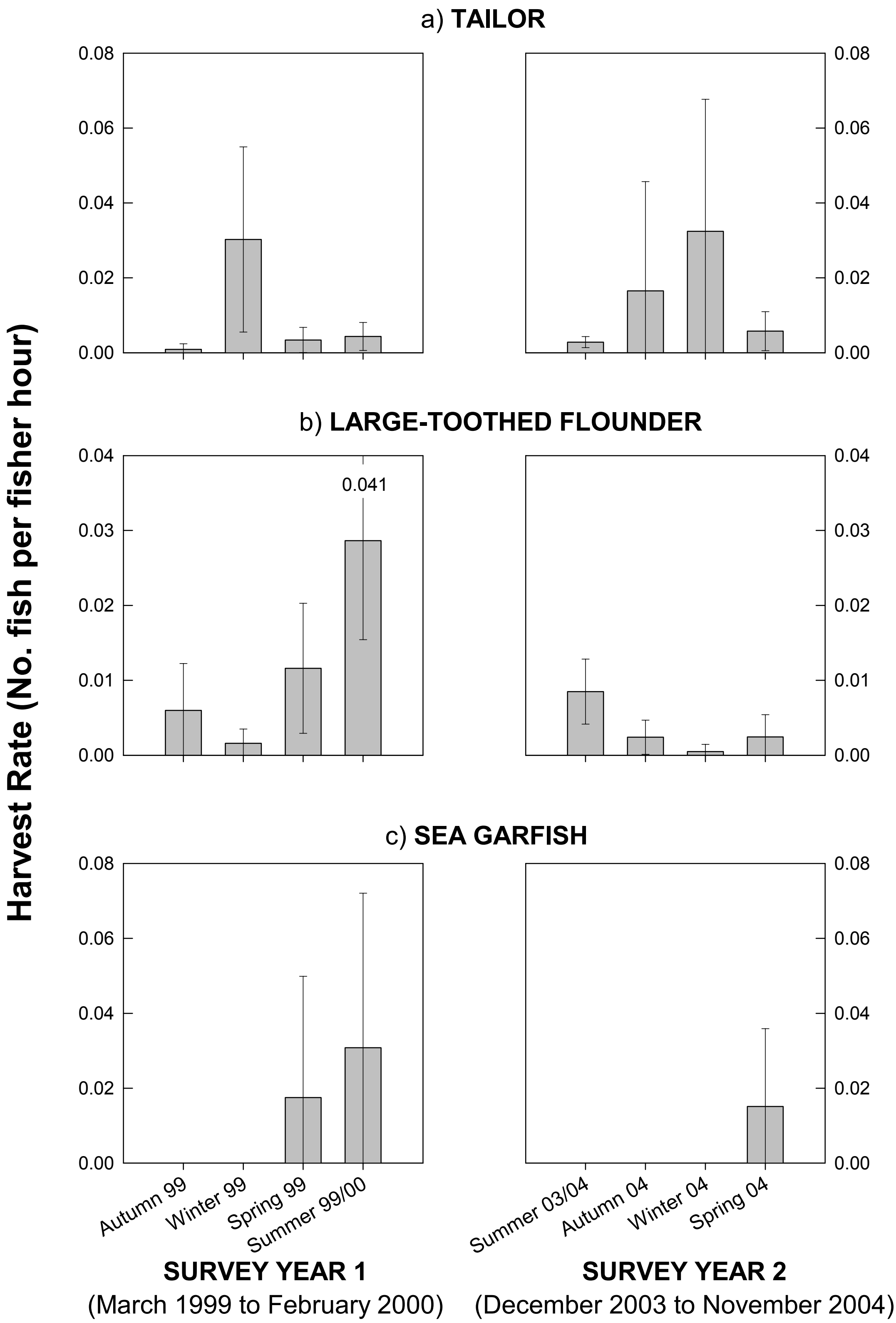

Figure 4. Recreational harvest rate estimates (fish per fisher hour) and 95% confidence intervals for a) tailor, b) large-toothed flounder and c) sea garfish taken by recreational fishers in the Tuross Lake boat-based recreational fishery for each survey year.

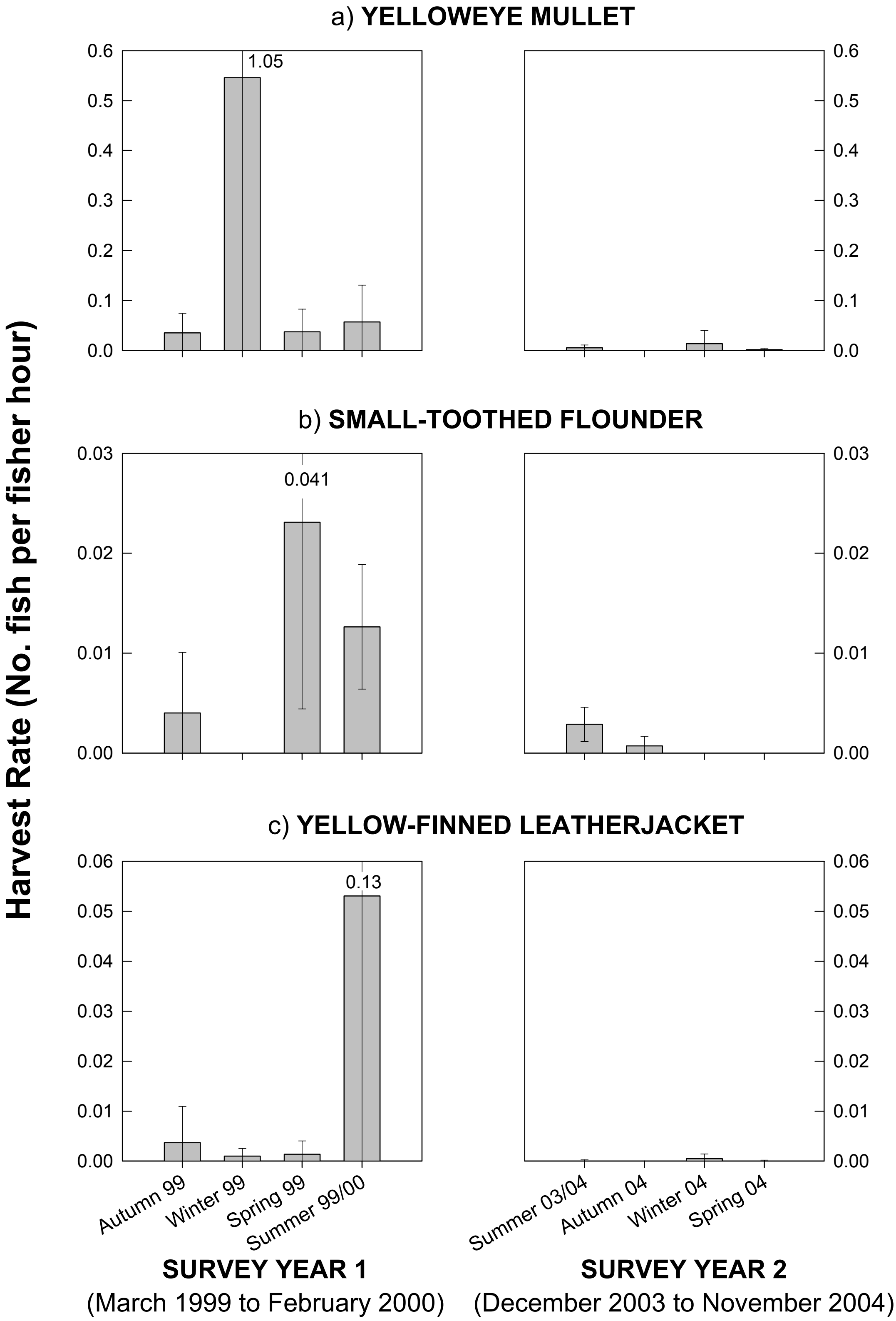

Figure 5. Recreational harvest rate estimates (fish per fisher hour) and 95% confidence intervals for a) yelloweye mullet, b) small-toothed flounder and c) yellow-finned leatherjacket taken by recreational fishers in the Tuross Lake boat-based fishery for each survey year.

4.3.2. Size-frequency distributions

Descriptive statistics of all measurements taken for each taxon by boat-based fishers during each survey period are presented in Appendix 2. Here, we present length frequency distributions and comparisons between survey periods for the main species of recreational importance. Data for all 12 main species are presented even though the available sample size may be small in one of the survey years. Comparisons should be viewed with caution whenever less than 50 measurements are available for a species in a survey year.

4.3.2.1. Dusky flathead

A comparison of the length frequency distributions between the two survey periods shows that the fish taken during the second survey year were, on average, larger than those harvested during the first survey year (Fig. 6). Dusky flathead harvested during the second survey year had larger mean and median fork lengths but it should be noted that the minimum legal length for this species was increased from 33 cm total length to 36 cm total length in the period between the surveys (Fig. 6).

4.3.2.2. Yellowfin bream

A comparison of the length frequency distributions between the two survey periods shows some similarity between survey years (Fig. 7). There was no change in the mean and median fork lengths of yellowfin bream between survey years (Fig. 7).

4.3.2.3. Sand whiting

A comparison of the length frequency distributions between the two survey periods shows that the fish taken during the second survey year were, on average, larger than those harvested during the first survey year (Fig. 8). Sand whiting harvested during the second survey year had larger mean and median fork lengths (Fig. 8).

4.3.2.4. River garfish

A comparison of the length frequency distributions between the two survey periods shows that the river garfish taken during the second survey year were, on average, larger than those harvested during the first survey year (Fig. 9). River garfish harvested during the second survey year had larger mean and median fork lengths (Fig. 9).

4.3.2.5. Sand mullet

A comparison of the length frequency distributions between the two survey periods shows that the fish taken during the second survey year were, on average, larger than those harvested during the first survey year (Fig. 10). Sand mullet harvested during the second survey year had larger mean and median fork lengths (Fig. 10), however, it should be noted that the available sample size was small for the first survey year.

4.3.2.6. Luderick

A comparison of the length frequency distributions between the two survey periods shows great similarity between the first and second survey year (Fig. 11). There was no change in the mean fork length between years but the median fork length increased by one centimetre in the second survey year (Fig. 11).

4.3.2.7. Tailor

A comparison of the length frequency distributions between the two survey periods shows that tailor taken during the second survey year were, on average, larger than those harvested during the first survey year (Fig. 12). Tailor harvested during the second survey year had larger mean and median fork lengths (Fig. 12), however, it should be noted that the available sample size was small for the first survey year.

4.3.2.8. Large-toothed flounder

A comparison of the length frequency distributions between the two survey periods shows that large-toothed flounder taken during the second survey year were, on average, larger than those harvested during the first survey year (Fig. 13). Large-toothed flounder harvested during the second survey year had larger mean and median total lengths (Fig. 13).

4.3.2.9. Sea garfish

A comparison of the length frequency distributions between the two survey periods shows that sea garfish taken during the second survey year were, on average, smaller than those harvested during the first survey year (Fig. 14). Sea garfish harvested during the second survey year had smaller mean and median fork lengths (Fig. 14).

4.3.2.10. Yelloweye mullet

A comparison of the length frequency distributions between the two survey periods shows that yelloweye mullet taken during the second survey year were, on average, larger than those harvested during the first survey year (Fig. 15). Yelloweye mullet harvested during the second survey year had larger mean and median fork lengths (Fig. 15), however, it should be noted that the available sample size was small for the second survey year.

4.3.2.11. Small-toothed flounder

A comparison of the length frequency distributions between the two survey periods shows that small-toothed flounder taken during the second survey year were, on average, larger than those harvested during the first survey year (Fig. 16). Small-toothed flounder harvested during the second survey year had larger mean and median total lengths (Fig. 16), however, it should be noted that the available sample size was small for the second survey year.

4.3.2.12. Yellow-finned leatherjacket

Only four measurements of yellow-finned leatherjacket were available for the second survey year (Fig. 17). Meaningful comparisons of length frequency data between survey years are impossible. Length frequency data for the first survey year are plotted (Fig. 17).

DUSKY FLATHEAD

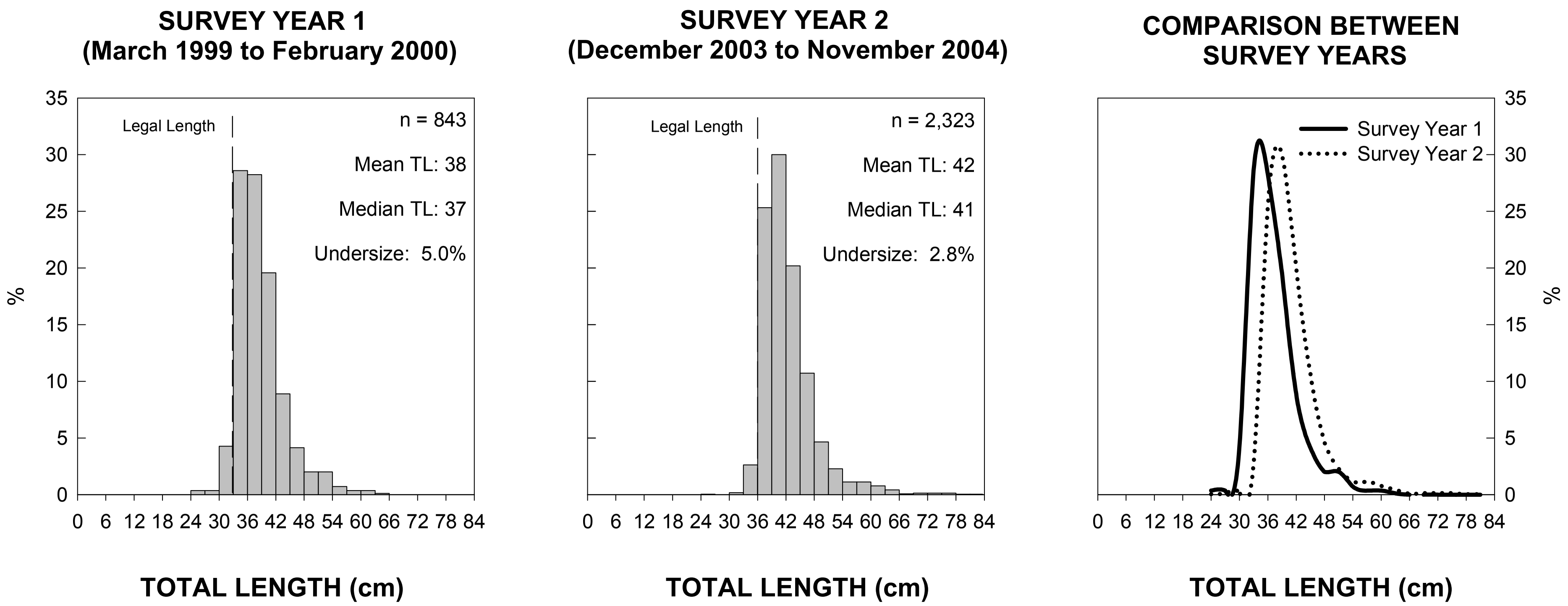

Figure 6. Dusky flathead – annual length frequency distributions and comparisons between survey years for the recreational boat-based fishery in Tuross Lake.

YELLOWFIN BREAM

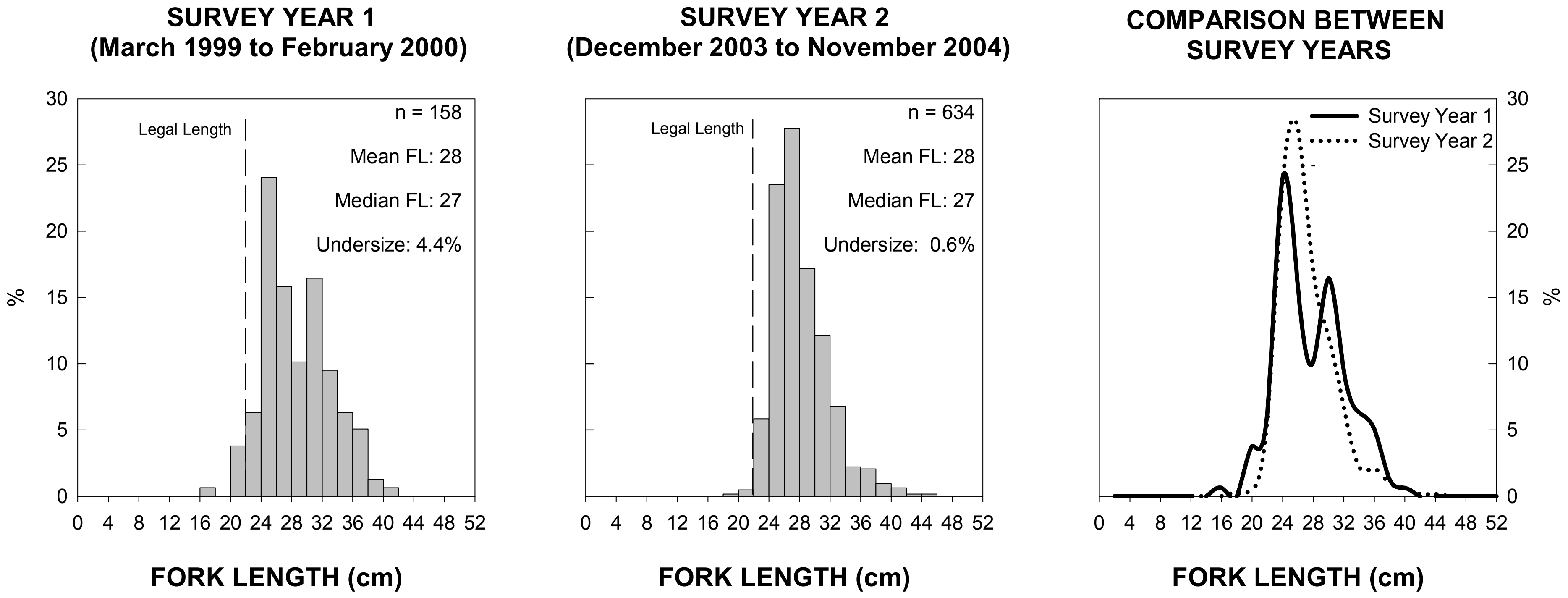

Figure 7. Yellowfin bream – annual length frequency distributions and comparisons between survey years for the recreational boat-based fishery in Tuross Lake.

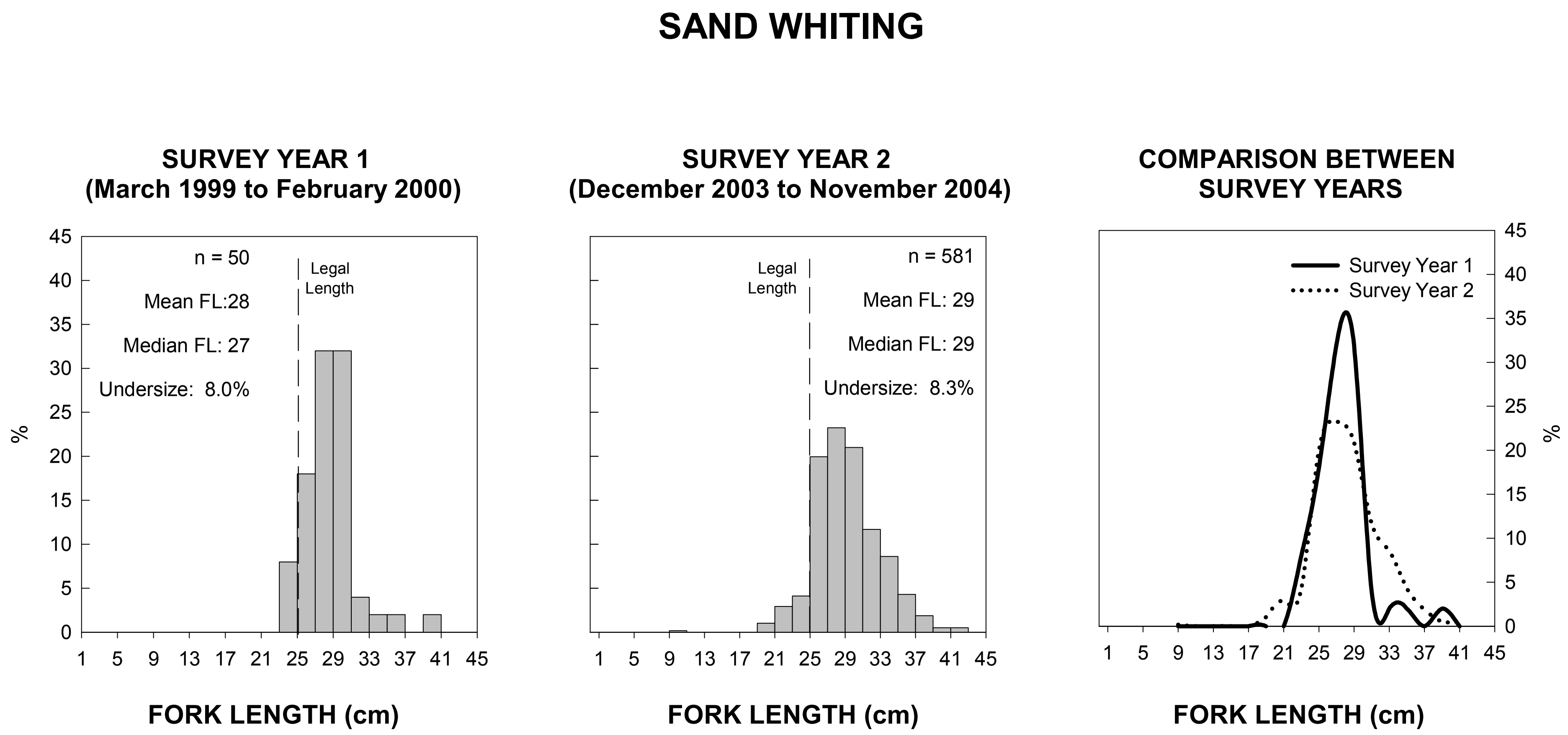

Figure 8. Sand whiting – annual length frequency distributions and comparisons between survey years for the recreational boat-based fishery in Tuross Lake.

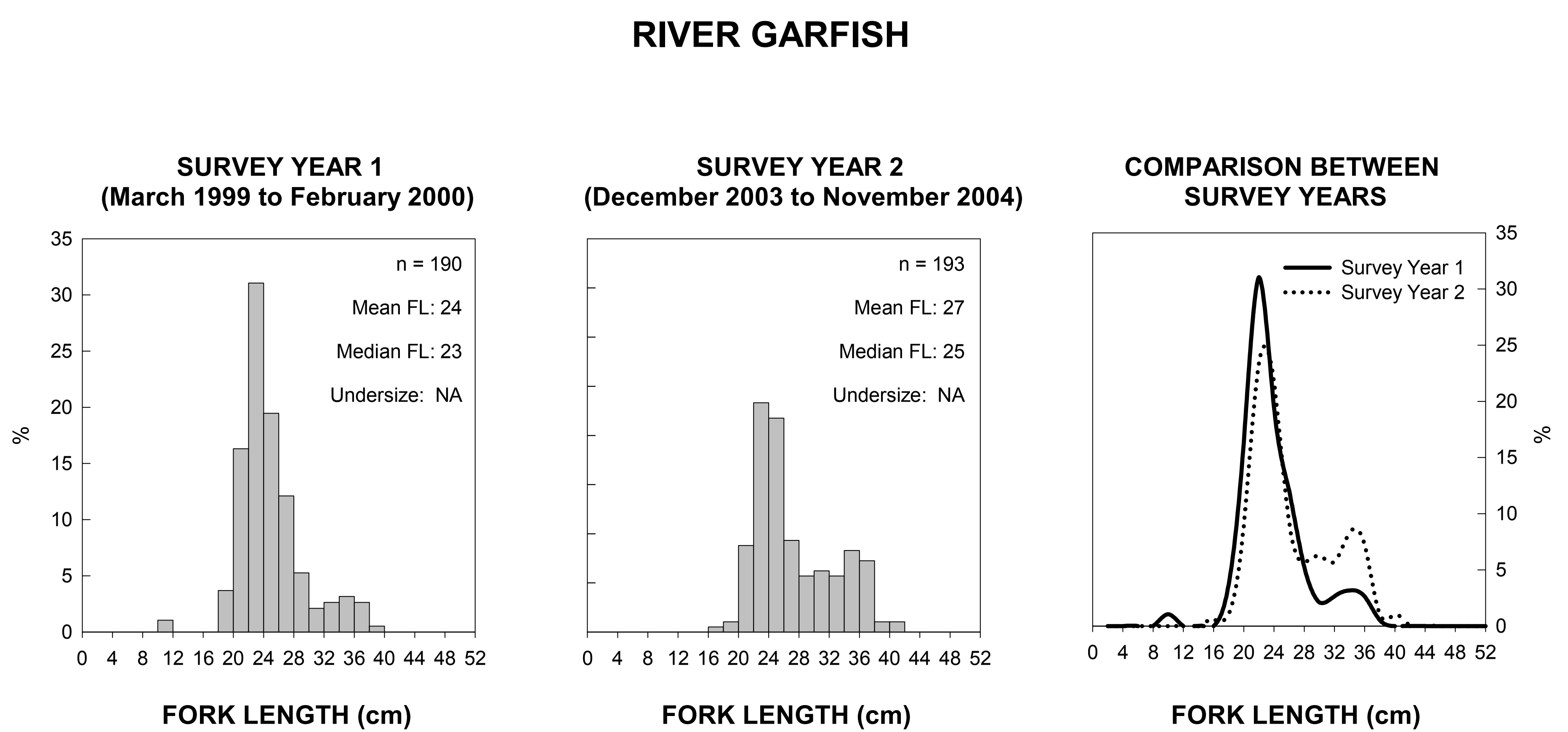

Figure 9. River garfish – annual length frequency distributions and comparisons between survey years for the recreational boat-based fishery in Tuross Lake.

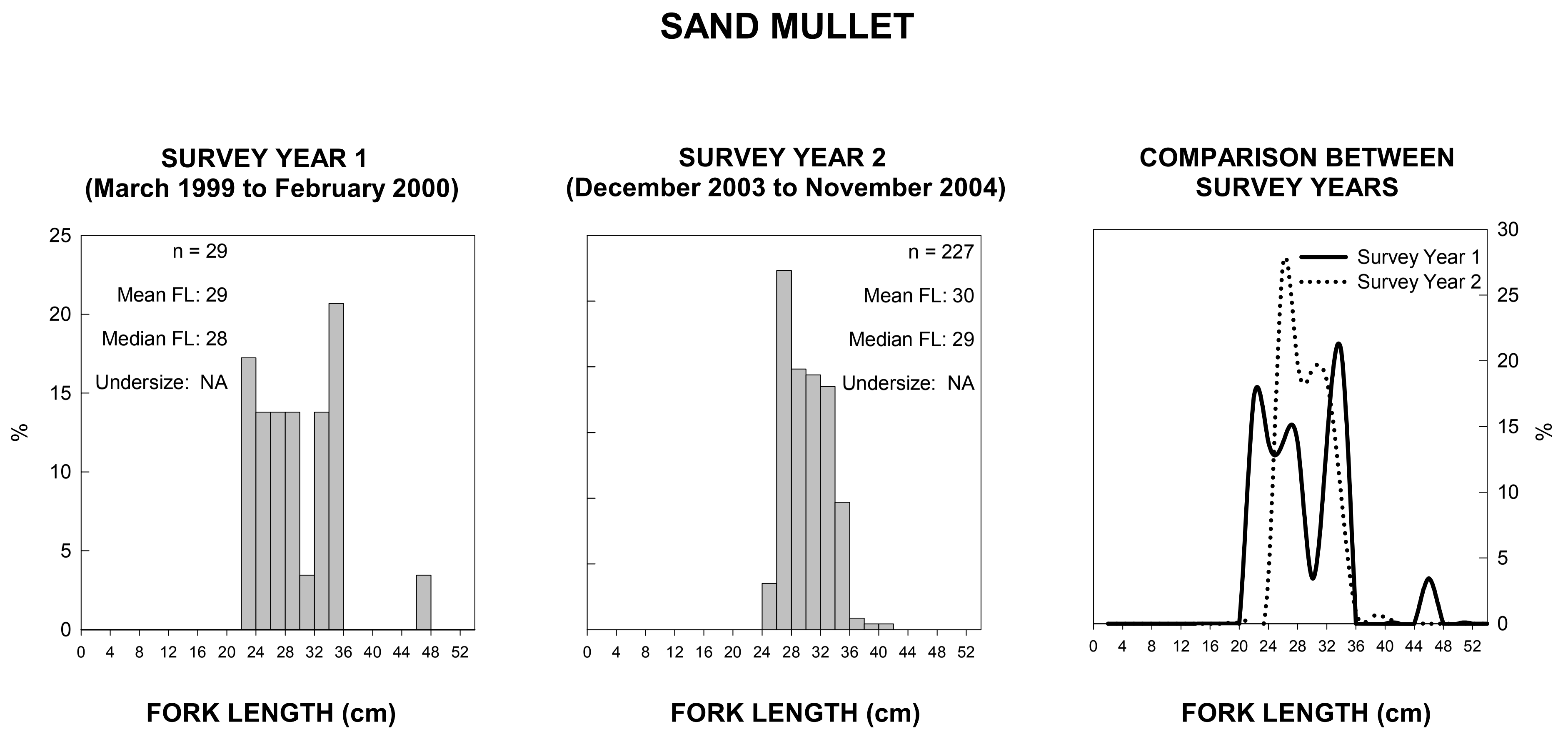

Figure 10. Sand mullet – annual length frequency distributions and comparisons between survey years for the recreational boat-based fishery in Tuross Lake.

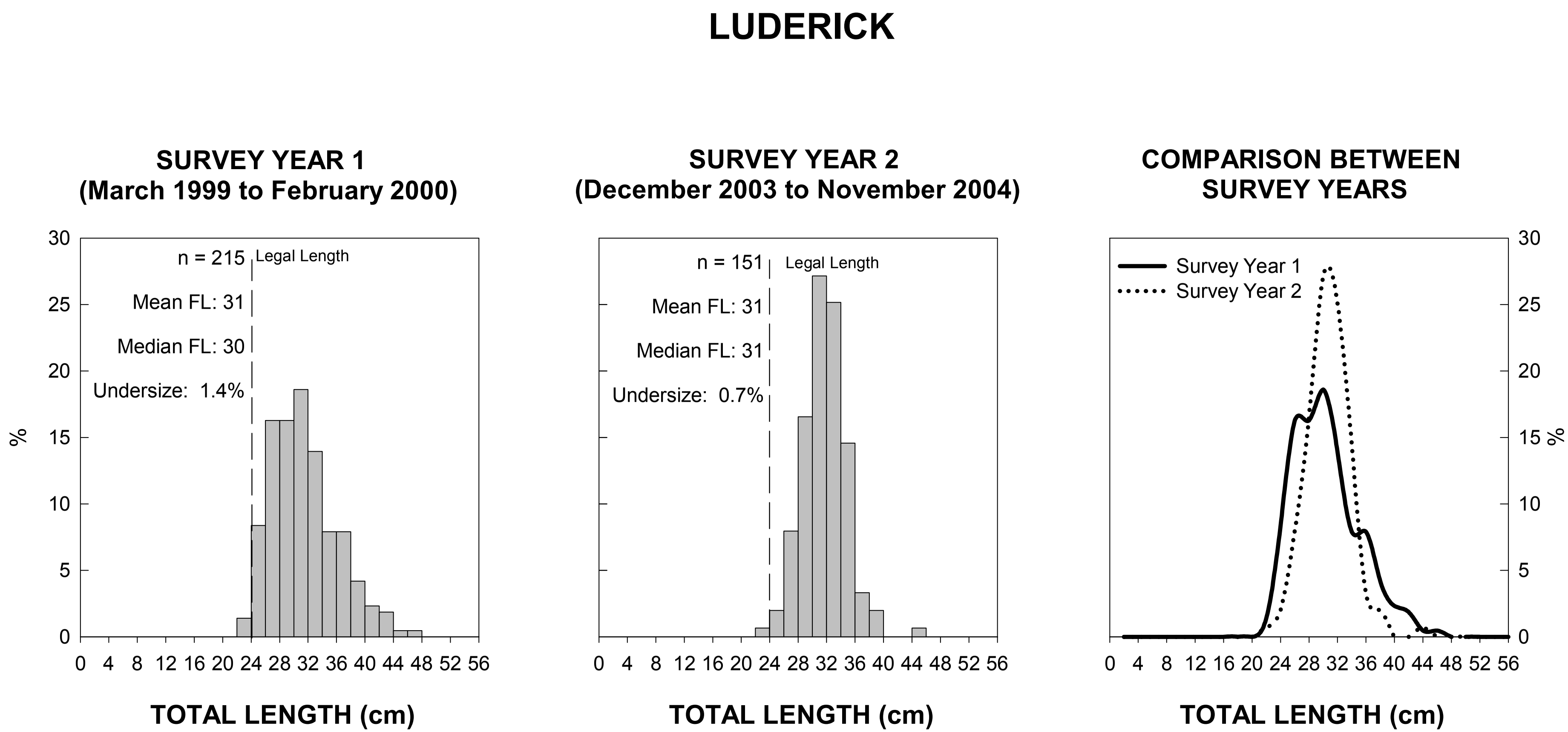

Figure 11. Luderick – annual length frequency distributions and comparisons between survey years for the recreational boat-based fishery in Tuross Lake.

TAILOR

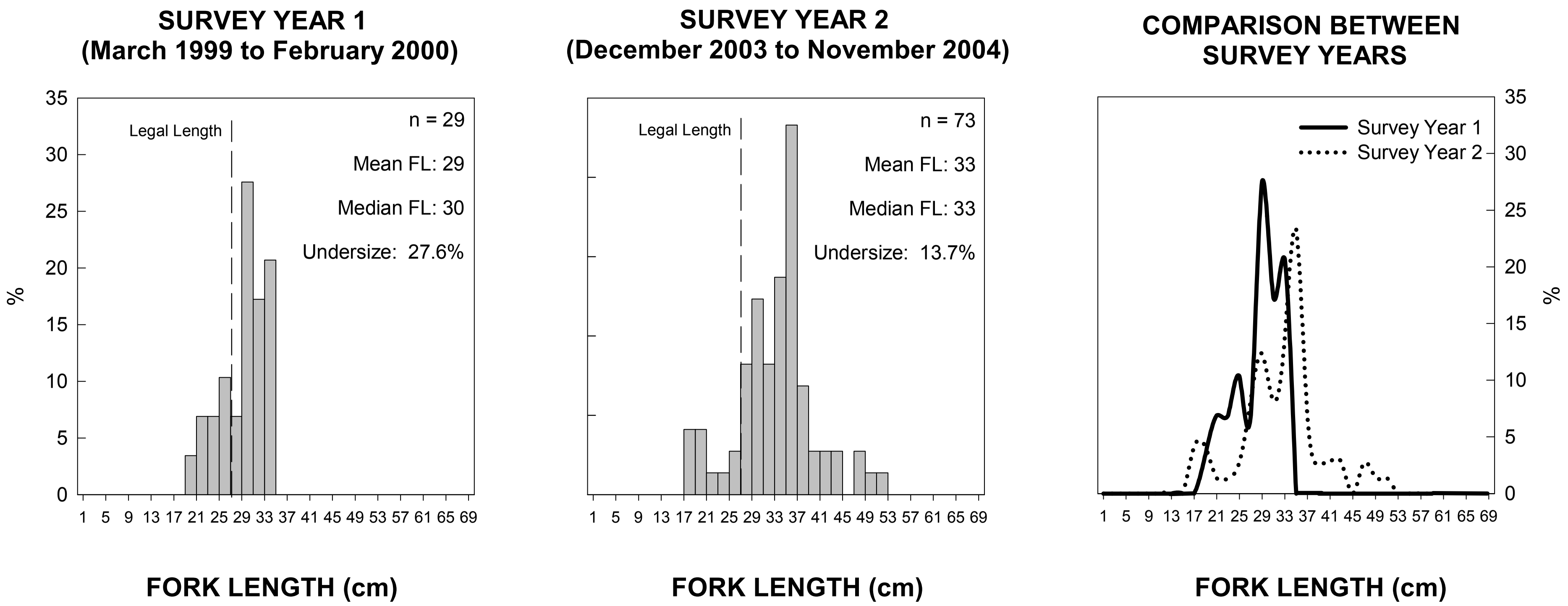

Figure 12. Tailor – annual length frequency distributions and comparisons between survey years for the recreational boat-based fishery in Tuross Lake.

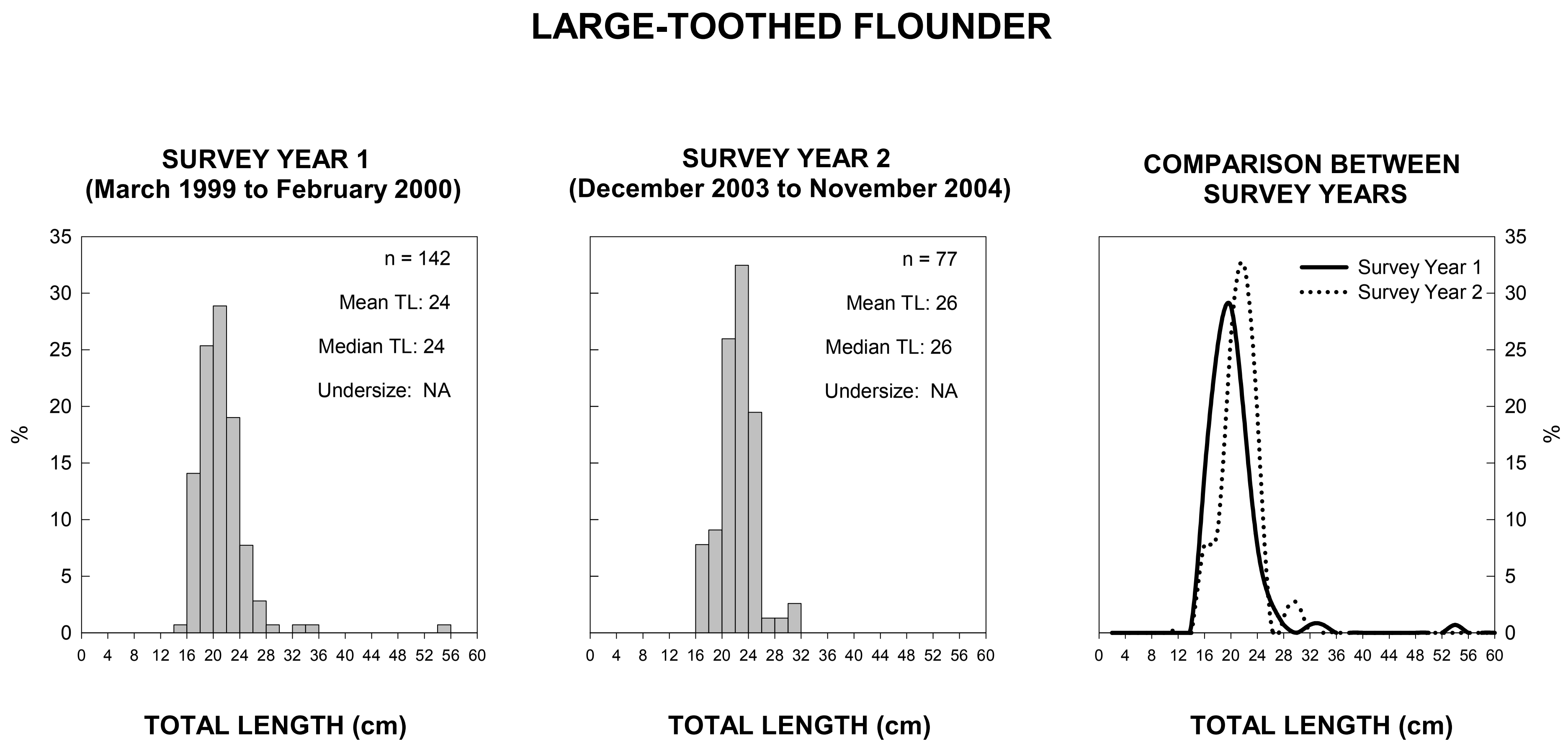

Figure 13. Large-toothed flounder – annual length frequency distributions and comparisons between survey years for the recreational boat-based fishery in Tuross Lake.

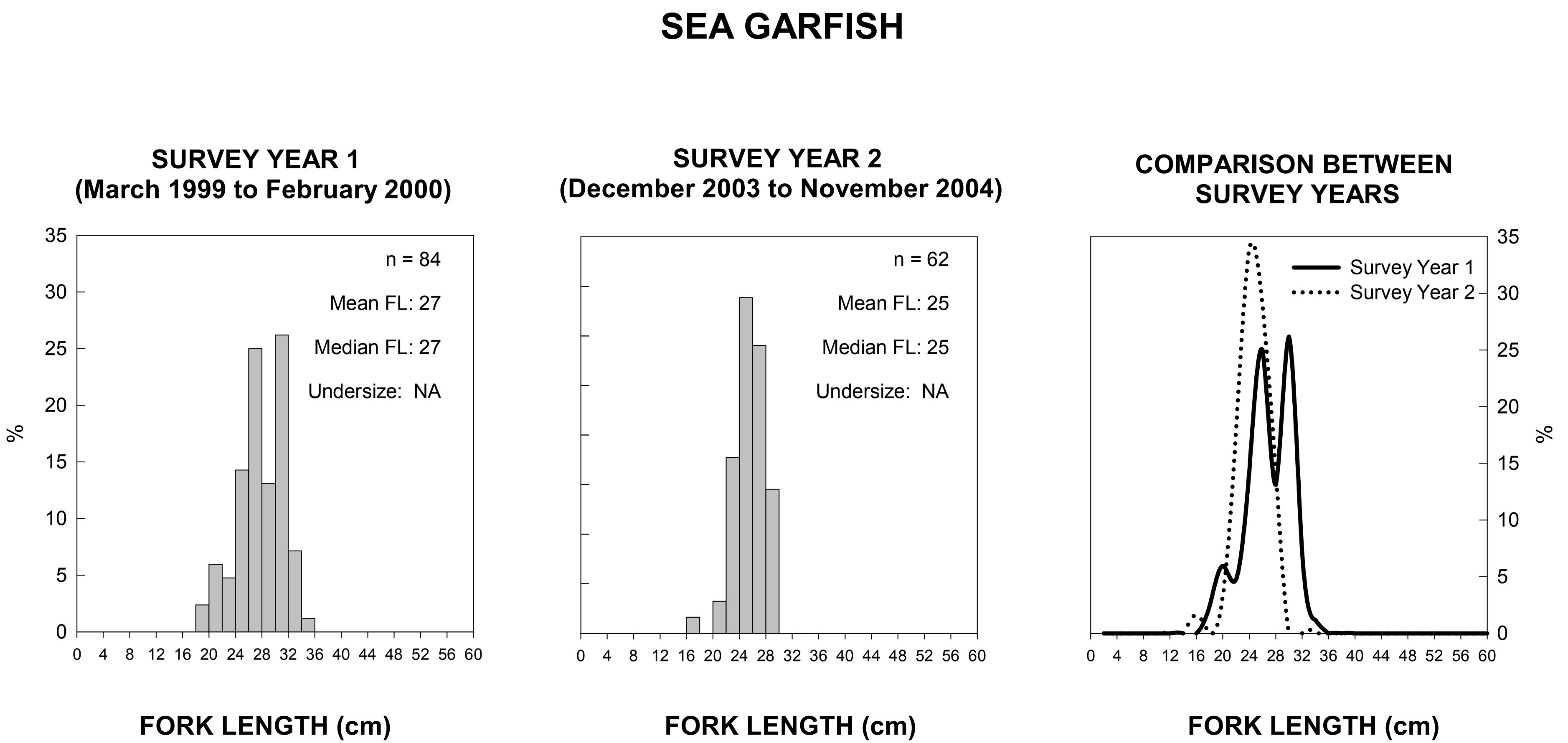

Figure 14. Sea garfish – annual length frequency distributions and comparisons between survey years for the recreational boat-based fishery in Tuross Lake.

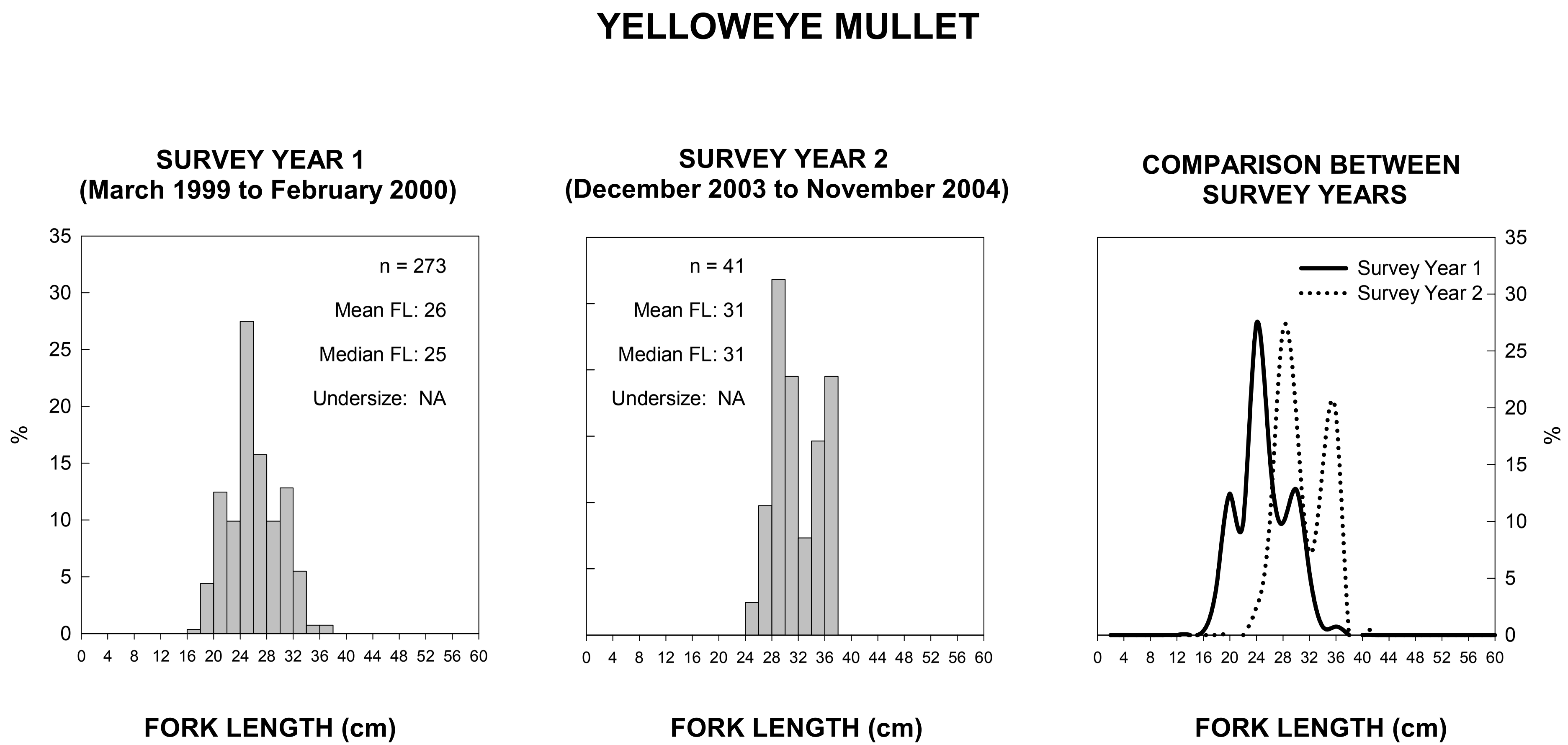

Figure 15. Yelloweye mullet – annual length frequency distributions and comparisons between survey years for the recreational boat-based fishery in Tuross Lake.

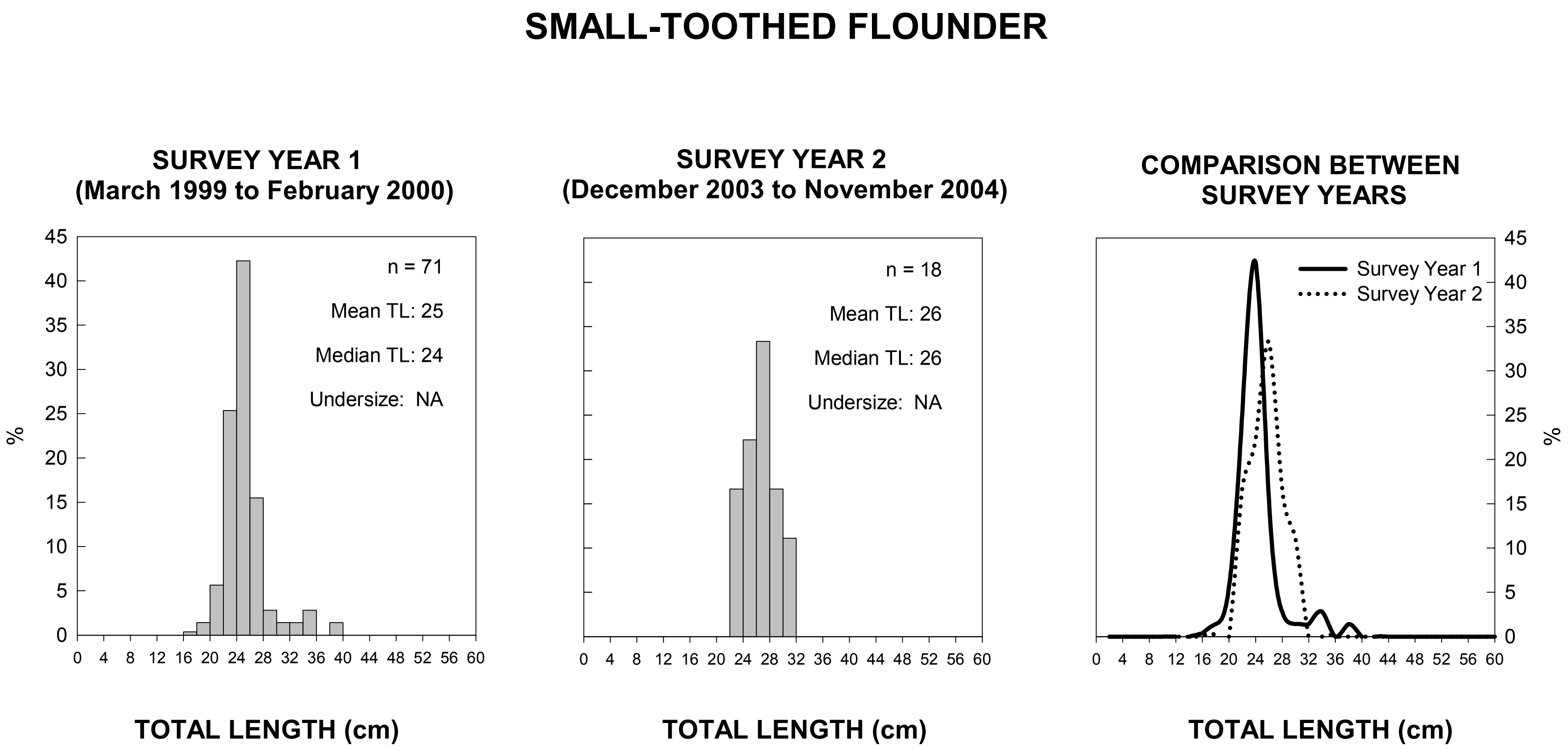

Figure 16. Small-toothed flounder – annual length frequency distributions and comparisons between survey years for the recreational boat-based fishery in Tuross Lake.

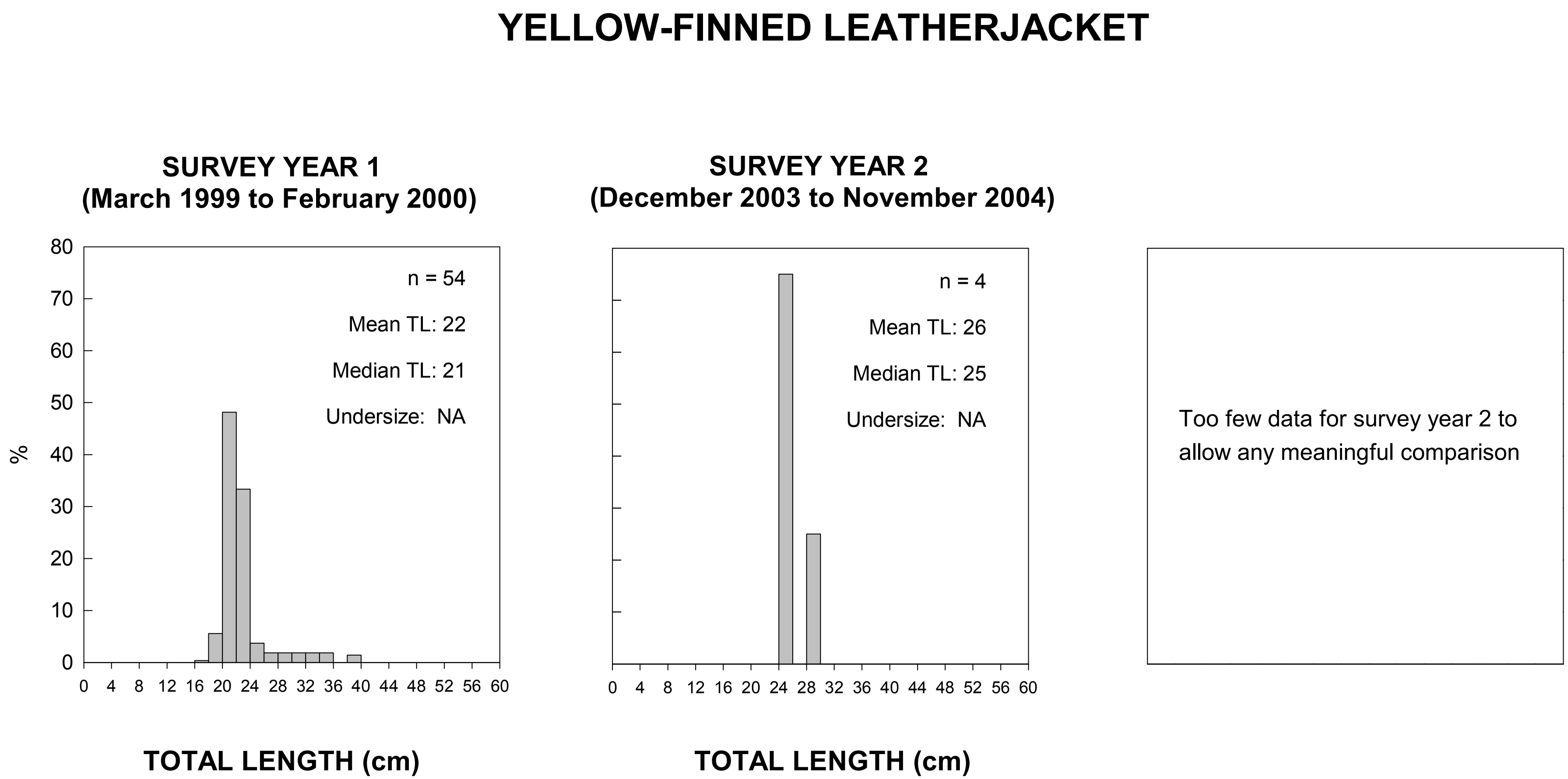

Figure 17. Yellow-finned leatherjacket – annual length frequency distributions for each survey year for the recreational boat-based fishery in Tuross Lake.

5. DISCUSSION

The establishment of the Tuross Lake estuary as a Recreational Fishing Haven (RFH) has changed the allocation of fisheries resources in this waterway between the recreational and commercial sectors. The removal of access for commercial fishers to Tuross Lake occurred during May 2002 thereby creating additional recreational fishing opportunities. This report focuses on comparisons made between two separate daytime, boat-based, recreational fishing surveys of the Tuross Lake estuary. The first annual survey was done during the pre-RFH period (March 1999 to February 2000) and the second annual survey was done during the post-RFH period (December 2003 to November 2004). These annual surveys provide a snapshot of the recreational fishery of Tuross Lake before RFH implementation and after RFH implementation. However, the representativeness of these two unreplicated survey periods as measures of pre-RFH and post-RFH conditions within the recreational fishery of the Tuross Lake estuary remains unknown.

The assessment of environmental disturbance or impacts arising from management interventions is made difficult because it is often uncertain whether a causal relationship exists between the management event (e.g. establishment of a RFH) that has occurred and any changes in fish populations or the recreational fishery that are measured at a later time. The changes in the recreational fishery that have been detected following the implementation of the RFH may be in part attributable to the impact of the management intervention and/or may be in part attributable to natural fluctuations in fish abundance and catchability. These can be large in an open system that allows migratory fish stocks to enter and leave the estuary. Nonetheless, the comparison between the two annual survey periods does show that real differences have occurred in the boat-based fishery in the Tuross Lake estuary since the first pre-RFH survey period.

Have there been changes in the recreational fishery since the exclusion of commercial fishing by the establishment of Tuross Lake as a RFH? In an extractive fishery the estimation of harvest provides a direct measure of the impact of fishing. Thus, changes in the harvest (number and weight of fish, crabs and cephalopods) and the relative composition of the harvest between annual survey periods are important measures that were used to assess change in the recreational fishery through time. We found a small, but not statistically significant increase, by number (4.4%, $p>0.05$), in the annual harvest of fish, crabs and cephalopods between survey periods for the boat-based fishery (Table 7). In contrast, there was a significant increase, by weight (41.6%, $p<0.05$), in the annual harvest of fish, crabs and cephalopods taken during the second survey year (Table 8). The recreational harvest in both survey years was dominated by relatively few taxa, however, the composition and relative contribution of these dominant taxa changed markedly between survey years (Tables 7 & 8). The recreational harvest of dusky flathead (77.2% by number, 142.3% by weight) and sand whiting (834.8% by number, 1058.0% by weight) was significantly greater ($p<0.05$) in the second survey year (Tables 7 & 8). There was also evidence of significantly increased harvest levels during the second survey year for yellowfin bream (112.3% by number – Table 7) and sand mullet (424.7% by weight – Table 8). The harvest of yellowfin bream (69.1% by weight), sand mullet (199.8% by number) and tailor (48.7% by number, 202.3% by weight) was greater in the second survey year but these changes were not statistically significantly different (Tables 7 & 8). In contrast, the recreational harvest of luderick (-66.3% by number, -66.2% by weight), yelloweye mullet (-95.6% by number, -91.6% by weight), large-toothed flounder (-61.7% by number, -53.7% by weight) and small-toothed flounder (-84.7% by number, -81.0% by weight) was significantly less ($p<0.05$) in the second survey year (Tables 7 & 8). The harvest of yellow-finned leatherjacket (-99.3% by number, -98.9% by weight) and sea garfish (-74.0% by number, -80.3% by weight) was much lower during the second survey year but these changes were not statistically significantly different (Tables 7 & 8). The harvest of river garfish was lower (-24.8% by number) during the second survey period but stable (0.9% by weight). These changes in the harvest levels of river garfish were not statistically significantly different between survey years (Tables 7 & 8). These findings indicate that the post-RFH recreational fishery in the Tuross Lake estuary was very different to the fishery that had existed prior to the implementation of the RFH.

A better understanding of these changes between survey periods in the boat-based recreational fishery of the Tuross Lake estuary can be achieved by considering the factors that influence the size of harvest levels and how they may have changed since the first survey year. The major factors that influence the size of the recreational harvest are fishing effort, harvest rates and the size of fish, crabs and cephalopods taken. A discussion of each of these main factors follows.

Fishing effort can influence the total harvest in two ways. Fishing effort can have a direct effect as measured by absolute changes in the time spent fishing (assuming harvest rate remains constant) and also an indirect effect which could be due to changes in the direction or targeting of fishing effort. The fishing effort (number of boat trips) expended in the fishery increased significantly by about 25.2% during the second survey year. This additional boat-based fishing effort may have contributed to increases in harvest levels. However, the observed changes (increases or decreases) in harvest levels for different species cannot be explained by this increase in fishing effort alone. For example, the proportional increases in recreational harvest (number and weight) between survey years for dusky flathead, yellowfin bream, sand whiting and sand mullet were all much larger than the corresponding proportional change in fishing effort.

Changes in targeting may also help explain changes in harvest between survey years. It is plausible that less favoured species are targeted by recreational fishers whenever it becomes difficult to catch their favoured species. This behaviour leads to the targeting of whatever is available at the time and usually occurs when favoured species are less accessible to the recreational fishery. For example, changes in targeting behaviour would be expected to shift away from favoured species during periods of low abundance, low catchability or when the available resource is being used heavily by many commercial and recreational users as in the case of the pre-RFH fishery in the Tuross Lake estuary. Conversely, changes in targeting behaviour would be expected to shift towards favoured species during periods of high abundance, high catchability or when the fishing pressure on the available resource is reduced by excluding a large user-group (i.e. the commercial sector) as in the case of the post-RFH fishery in the Tuross Lake estuary.

Do the seasonal harvest rate data indicate any major changes in fishing quality since the first survey year? Seasonal trends are evident in the harvest rate data, however, these data are highly variable making it difficult to detect statistically significant differences between survey years (see Figs. 2 to 5). The harvest of dusky flathead was shown to be significantly greater (number and weight) during the second survey year, however, the seasonal harvest rate data were too imprecise for the detection of any significant seasonal differences between survey years (Fig. 2a). Similarly, the seasonal harvest rates for luderick and yelloweye mullet were too imprecise to detect any significant seasonal differences between survey years (Figs. 3c & 4a) despite the harvests of both species declining significantly (number and weight) during the second survey period. The seasonal harvest rate data for river garfish, tailor, sea garfish and yellow-finned leatherjacket showed no significant differences between survey years (see Figs. 2-5) and this lack of detectable pattern between survey years was consistent with the harvest analyses for these species (Tables 7 & 8). In contrast, there were significant increases in seasonal harvest rates during the second survey year for yellowfin bream, sand whiting and sand mullet and significant decreases in seasonal harvest rates during the second survey year for large-toothed flounder and small-toothed flounder (see Figs. 2-5). The detection of significant seasonal harvest rate differences between corresponding seasons in different survey years (increases and decreases) for these species support the findings of the harvest analyses (Tables 7 & 8) and provide further evidence of major changes in the recreational fishery since the first survey period. These changes in seasonal harvest rates may be attributed to the effects of many inter-related factors, such as: (a) the availability of fish resulting from the removal of commercial fishing and/or natural fluctuations in abundance; (b) changes in targeting practices; and (c) increases in angler skill levels and technological improvements in fishing gear (e.g. the increased use of soft plastic lures may have led to increased harvest rates of yellowfin bream).

Is there any evidence to indicate that the size of fish has changed since the first survey year? Changes in the size of fish can be assessed: (a) directly by comparing length frequency distributions, and their associated mean and median lengths; and (b) indirectly by comparing proportional changes in harvest levels (total number of individuals compared to total weight) between survey years. The change in size is inferred whenever the percentage change in harvest by number differs from the percentage change in harvest by weight. For example, when the percentage change by weight is greater than the percentage change by number, it can be inferred that the average size of fish has increased. Conversely, when the percentage change in harvest by weight is less than the percentage change by number, it can be inferred that the average size of fish has decreased.

An examination of comparative length frequency information, mean and median lengths between survey years indicated that most species were harvested at larger sizes during the post-RFH survey year. The mean and median sizes of dusky flathead, sand whiting, river garfish and large-toothed flounder were all larger during the second survey year (Figs. 6, 8, 9 & 13). Similarly, the mean and median sizes of sand mullet, tailor, yelloweye mullet and small-toothed flounder were larger during the second survey year but these comparisons should be treated with caution because of small sample sizes (<50 fish per species) in one of the survey years (Figs. 10, 12, 15 & 16). The median size of luderick was larger during the second survey year (Fig. 11). Interestingly, the increases in the mean and median size of yelloweye mullet, large-toothed flounder, small-toothed flounder and luderick (median only) occurred during the second survey year when their estimated harvests (number and weight) had decreased significantly. Yellowfin bream had identical mean and median lengths during each of the survey years (Fig. 7). Sea garfish was the only species that showed a decrease in mean and median size during the second survey year (Fig. 14).

Similar observations were made when comparing the relative changes in harvest (percentage number versus percentage weight) for these same species and inferring size changes between survey years (see Tables 7 & 8). Increases in size during the second survey year were inferred for dusky flathead, sand whiting, river garfish, sand mullet, tailor, large-toothed flounder, yelloweye mullet and small-toothed flounder (Tables 7 & 8). A decrease in size was inferred for yellowfin bream and sea garfish (Tables 7 & 8). An inferred change in size was not evident for luderick or yellow-finned leatherjacket (Tables 7 & 8).

The length frequency data for dusky flathead are noteworthy for two main reasons. Firstly, the observed increase in mean size for dusky flathead was 4 cm, which was 1 cm more than the increase in minimum legal length that had been implemented since the first survey period. This indicates that there was a relatively small increase in fish size during the second survey period. Secondly, the length frequency data indicated that the population of dusky flathead in the Tuross Lake estuary were growth overfished. That is, the harvest of dusky flathead was dominated by relatively small fish and larger fish were relatively uncommon. For example, only 0.1% and 1.0% of dusky flathead were larger than 60 cm during the first and second survey years respectively. Growth overfishing can occur when excessive fishing effort (commercial and recreational) leads to the harvesting of many smaller fish and they do not get a chance to reach their maximum growth potential. Growth overfishing occurs in situations where the overall fishing mortality rate is very high. The implications for anglers of a stock that is growth overfished is that there will be very few large trophy fish in the available population. The dusky flathead population within the Tuross Lake estuary were fished heavily prior to the implementation of the RFH when commercial fishing was still allowed and the length frequency data from the first survey period support this interpretation. The relatively small improvement measured during the post-RFH survey period indicates that the increase in recreational fishing effort (about 25%) has been sufficiently large to offset most of the potential gain made by removing commercial fishing effort. This is not surprising given that dusky flathead is by far the main target species for recreational fishers in the Tuross Lake estuary and large amounts of fishing effort are directed at this species. The recent increased usage of soft plastic lures (which are very effective for catching flathead) may also have contributed to the observed increase in harvest level of dusky flathead. It would seem prudent to continue monitoring this recreational fishery at intervals of about 3 to 5 years and to also incorporate some biological sampling of key recreational species (e.g. age composition and reproductive biology) into any repeat survey work.

The removal of commercial fishing after the establishment of the RFH in 2002 meant that fish previously harvested by commercial fishers were now available to the recreational sector only. This management change may have led to an overall decrease in fishing pressure and a concomitant reduction in the rate of fishing mortality (commercial and recreational combined) on the fish stocks within the Tuross Lake estuary. Any reduction in fishing effort or fishing mortality rate may allow the standing stocks of fish, crabs and cephalopods some additional time to grow before they are harvested. If so, it would be expected that the mean and median sizes of many species should increase within the fishery. This is consistent with the increases in sizes observed for most species during the post-RFH survey year.

6. CONCLUSIONS

This recreational fishing survey provides evidence of a relatively productive recreational fishery in the Tuross Lake estuary. Comparisons made between two separate daytime surveys of boat-based recreational fishing (the first done during the pre-RFH period and this second survey done during the post-RFH period) indicate that the post-RFH recreational fishery was very different to the fishery that existed prior to the implementation of the RFH. We documented statistically significant increases in recreational harvest for some prized recreational species and also some significant decreases for some other important recreational species. Overall, the indicators of recreational fishing quality that we examined indicated that the post-RFH fishery had improved in many ways since the pre-RFH survey period. A summary of the evidence provided in this report is that:

1. the recreational harvest (number and weight) in both survey years was dominated by a relatively small number of taxa, however, the relative contribution of these dominant taxa changed markedly between survey years. These changes occurred even though there was no significant difference, by number, between survey years in the total annual harvest. A significant increase, by weight (41.6%), in the annual harvest of fish, crabs and cephalopods was recorded during the post-RFH survey year;

2. the recreational harvest of dusky flathead and sand whiting (number and weight), yellowfin bream (number only) and sand mullet (weight only) had increased significantly during the post-RFH survey year;

3. the recreational harvest of luderick, yelloweye mullet, large-toothed flounder and small-toothed flounder, by number and weight, had decreased significantly during the post-RFH survey year;

4. fishing effort (number of boat trips) increased significantly by about 25.2% during the post-RFH survey year;

5. significant harvest rate differences between corresponding seasons in the two survey years were detected. These significant differences in seasonal harvest rates between survey years indicate that major changes have occurred in the fishery since the pre-RFH survey period;

6. comparisons of length frequency information, mean and median lengths between survey years indicated that most species were harvested at larger sizes during the post-RFH survey year. The mean and median sizes of dusky flathead, sand whiting, river garfish and large-toothed flounder were all larger during the second survey year. Similarly, the mean and median sizes of sand mullet, tailor, yelloweye mullet and small-toothed flounder were larger during the post-RFH survey year but these comparisons should be treated with caution because of the small sample sizes (<50 fish per species) in one of the survey years;

7. the dusky flathead population within the Tuross Lake estuary was fished heavily prior to the implementation of the RFH when commercial fishing was still allowed. The length frequency data indicate that dusky flathead were growth overfished at the time of the pre-RFH survey. The relatively small improvement measured during the post-RFH survey indicates that the increase in recreational fishing effort of about 25% has been sufficiently large to offset most of the potential gain made by removing commercial effort.

7. RECOMMENDATIONS

1. This study provides annual snapshots (point estimates) of the daytime, boat-based recreational fishery in the Tuross Lake estuary prior to and following the establishment of the waterway as a RFH. On-site surveys of recreational fishing are valuable tools for collecting information to describe the status of a fishery and any changes that may have occurred since previous survey periods. On-site surveys of the recreational fishery should be repeated regularly (every 3-5 years) to monitor the recreational fishery in the Tuross Lake estuary.

2. It would be prudent and cost-effective to incorporate some biological sampling of key recreational species (e.g. age composition and reproductive biology) into any repeat survey work. Biological information will be invaluable for interpreting and understanding the factors that influence major changes in fish populations between survey periods.

3. The utility of auxiliary datasets (e.g. automated traffic records and boat-hire records) for improving the accuracy and precision of fishing effort and harvest estimates within this recreational fishery has been demonstrated. We recommend the use of these supplementary methods in any future survey of the Tuross Lake recreational fishery.

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9. APPENDICES

Appendix 1. Length to weight conversion keys used to estimate weights for various taxa. Relevant details which describe the sample material used to calculate the length to weight key is provided. In all length to weight keys the sexes have been combined.

Common Name	Taxon	Sample Size	Size Range (cm)	Length to Weight Key $W(grams) = a * L(cm)^b$	Adjusted r^2	Region of Sample	Source of Key
Bream, Yellowfin	*Acanthopagrus australis*	758	15.0 – 40.5	$W=0.024787915*FL^{2.99584}$	0.980	NSW	Steffe et al. (1996)
Bream, Black*	*Acanthopagrus butcheri*	-	- -	Yellowfin Bream Key Used	-	-	-
Crab, Blue Swimmer	*Portunus pelagicus*	186	1.3 – 9.3	$W=0.9219*CL^{2.8855}$	0.967	NSW	Ken Graham unpub. data
Crab, Mud	*Scylla serrata*	30	8.7 – 12.7	$W=15.9866*CL^{1.6375}$	0.346	NSW	Steffe & Chapman (2003)
Flathead, Southern Sand*	*Platycephalus bassensis*	-	- -	Eastern Blue-spotted Flathead Key Used	-	-	-
Flathead, Dusky	*Platycephalus fuscus*	589	20.3 – 88.0	$W=0.0026864577*FL^{3.22910}$	0.992	NSW	Steffe et al. (1996)
Flounder, Large-toothed	*Pseudorhombus arsius*	1061	15.0 – 31.5	$W=0.0053053006*FL^{3.18944}$	0.971	Botany Bay, NSW	Steffe et al. (1996)
Flounder, Small-toothed	*Pseudorhombus jenynsii*	138	15.0 – 33.4	$W=0.0014768963*FL^{3.62935}$	0.961	Botany Bay, NSW	Steffe et al. (1996)
Garfish, Sea	*Hyporhamphus australis*	259	10.2 – 31.5	$W=0.0008*FL^{3.4561}$	0.971	Botany Bay, NSW	SPCC (1981)
Garfish, River*	*Hyporhamphus regularis*	-	- -	Sea Garfish Key Used	-	-	-
Gurnard, Red	*Chelidonichthys kumu*	553	10.0 43.5	$W=0.0081543622*FL^{3.09853}$	0.990	NSW	Steffe et al. (1996)
Leatherjacket, Six-spined	*Meuschenia freycineti*	223	10.0 – 41.0	$W=0.016472898*FL^{3.01383}$	0.994	NSW	Steffe et al. (1996)
Leatherjacket, Yellow-finned	*Meuschenia trachylepis*	570	5.0 – 35.0	$W=0.0078*FL^{3.2233}$	0.962	Botany Bay, NSW	SPCC (1981)
Luderick	*Girella tricuspidata*	186	10.0 – 38.8	$W=0.0099659797*FL^{3.22212}$	0.990	Botany Bay, NSW	SPCC (1981)
Mullet, Yelloweye	*Aldrichetta forsteri*	50	Not Given	$W=0.0101*FL^{3.108}$	Not Given	Gippsland Lakes (Vic)	Hall & MacDonald (1985)
Mullet, Sea	*Mugil cephalus*	216	6.9 – 43.8	$W=0.0078*FL^{3.2097}$	0.970	Botany Bay, NSW	SPCC (1981)
Mullet, Sand	*Myxus elongatus*	336	10.0 – 39.5	$W=0.0097*FL^{3.0967}$	0.963	Botany Bay, NSW	SPCC (1981)
Salmon	*Arripis trutta*	8232	4.0 – 77.0	$W=0.0132678*FL^{3.0485}$	Not Given	Australia	Malcolm (1966)
Snapper	*Pagrus auratus*	2646	6.5 – 82.0	$W=0.0467727*FL^{2.781}$	0.990	W.A.	Moran & Burton (1990)
Tarwhine	*Rhabdosargus sarba*	730	10.0 – 30.5	$W=0.014914888*FL^{3.16297}$	0.986	NSW	Steffe et al. (1996)
Tailor	*Pomatomus saltatrix*	1028	10.0 – 58.5	$W=0.0075039512*FL^{3.15753}$	0.994	NSW	Steffe et al. (1996)
Trevally, Silver	*Pseudocaranx dentex*	43	19.5 – 39.0	$W=0.033516603*FL^{2.84574}$	0.991	NSW	Steffe et al. (1996)
Whiting, Sand	*Sillago ciliata*	1198	10.0 – 39.5	$W=0.0040*FL^{3.3137}$	0.973	Botany Bay, NSW	SPCC (1981)

Steffe et al. (1996). - refers to the amalgamation of material from a variety of sources and the recalculation of a length to weight key. These sources include material from market measuring, ramp measuring, and unpublished material taken from the Botany Bay project (SPCC, 1981), the Northern Rivers project and the Deep Ocean Outfall Monitoring project.
* Length to weight equation for this taxon was not available. Estimates of weight were obtained by using a length to weight key for a closely related taxon.
FL - Fork Length, CL - Carapace Length.

Appendix 2. The number of individuals observed (N), the number of individuals measured (n), size range (cm), median length (cm), and mean lengths (cm) for all taxa taken by boat-based recreational fishers in the Tuross Lake estuary during the two annual survey periods.

	SURVEY YEAR 1 (March 1999 to February 2000)					SURVEY YEAR 2 (December 2003 to November 2004)				
TAXON	N	n	Range	Median	Mean	N	n	Range	Median	Mean
Bream, Black *Acanthopagrus butcheri*	5	5	24 to 35	31	29.6	33	31	23 to 38	27	29.3
Bream, Yellowfin *Acanthopagrus australis*	166	155	17 to 40	27	28.3	664	634	19 to 44	27	27.6
Cod, Black * *Epinephelus daemelii*	-	-	-	-	-	1	1	32	32	32.0
Crab, Blue Swimmer *Portunus pelagicus*	5	5	7 to 9	8	8.2	38	34	6 to 14	10	9.6
Crab, Mud *Scylla serrata*	-	-	-	-	-	15	13	9 to 15	13	12.9
Flathead, Dusky *Platycephalus fuscus*	925	843	25 to 63	37	38.2	2413	2323	26 to 82	41	41.8
Flathead, Eastern Blue-Spotted *Platycephalus caeruleopunctatus*	1	1	37	37	37.0	-	-	-	-	-
Flathead, Marbled *Platycephalus marmoratus*	-	-	-	-	-	1	1	27	27	27.0
Flathead, Southern Sand *Platycephalus bassensis*	6	6	33 to 35	33	33.7	1	1	37	37	37.0
Flounder, Large-Toothed *Pseudorhombus arsius*	151	142	14 to 55	24	24.4	79	77	20 to 34	26	25.8
Flounder, Small-Toothed *Pseudorhombus jenynsii*	72	71	19 to 38	24	24.8	18	18	22 to 30	26	25.9

Appendix 2 (continued)

TAXON	SURVEY YEAR 1 (March 1999 to February 2000)					SURVEY YEAR 2 (December 2003 to November 2004)				
	N	n	Range	Median	Mean	N	n	Range	Median	Mean
Garfish, River *Hyporhamphus regularis*	246	190	11 to 38	23	24.4	242	193	17 to 41	25	26.8
Garfish, Sea *Hyporhamphus australis*	95	84	19 to 34	27	27.3	62	62	17 to 29	25	25.1
Grinner, Painted *Trachinocephalus myops*	-	-	-	-	-	1	1	28	28	28.0
Gurnard, Red *Chelidonichthys kumu*	4	3	29 to 29	29	29.0	5	5	26 to 34	30	30.4
Leatherjacket, Chinaman *Nelusetta ayraudi*	1	1	24	24	24.0	1	1	20	20	20.0
Leatherjacket, Fan-Bellied *Monacanthus chinensis*	-	-	-	-	-	1	1	36	36	36.0
Leatherjacket, Six-Spined *Meuschenia freycineti*	4	4	20 to 24	22	22.0	-	-	-	-	-
Leatherjacket, Yellow-Finned *Meuschenia trachylepis*	122	54	19 to 34	21	22.2	4	4	24 to 29	24.5	25.5
Longtom, Stout *Tylosurus gavialoides*	-	-	-	-	-	2	2	44 to 75	59.5	59.5
Luderick *Girella tricuspidata*	264	215	23 to 47	30	30.9	165	151	23 to 44	31	31.3
Mackerel, Slimy *Scomber australasicus*	-	-	-	-	-	2	2	27 to 28	27.5	27.5

	SURVEY YEAR 1 (March 1999 to February 2000)					SURVEY YEAR 2 (December 2003 to November 2004)				
TAXON	N	n	Range	Median	Mean	N	n	Range	Median	Mean
Mullet, Flat-Tail *Liza argentea*	1	1	30	30	30.0	-	-	-	-	-
Mullet, Sand *Myxus elongatus*	59	29	22 to 46	28	29.1	230	227	25 to 40	29	29.7
Mullet, Sea *Mugil cephalus*	39	29	19 to 35	24	24.9	3	3	33 to 42	34	36.3
Mullet, Yelloweye *Aldrichetta forsteri*	352	273	16 to 37	25	25.5	43	41	25 to 37	31	31.4
Mulloway *Argyrosomus japonicus*	1	1	49	49	49.0	2	2	76 to 81	78.5	78.5
Ray, Shovelnose *Aptychotrema rostrata*	3	3	88 to 98	90	92.0	-	-	-	-	-
Salmon, Australian *Arripis trutta*	5	5	39 to 50	43	43.4	14	10	24 to 55	35.5	37.0
Scorpioncod, Red *Scorpaena cardinalis*	1	1	45	45	45.0	-	-	-	-	-
Silver Biddy *Gerres subfasciatus*	-	-	-	-	-	24	24	8 to 17	12.5	12.6
Snapper *Pagrus auratus*	3	3	12 to 17	13	14.0	23	23	20 to 32	24	25.0
Tailor *Pomatomus saltatrix*	40	29	20 to 34	30	28.9	77	73	17 to 53	33	32.7

Appendix 2 (continued)

TAXON	SURVEY YEAR 1 (March 1999 to February 2000)					SURVEY YEAR 2 (December 2003 to November 2004)				
	N	n	Range	Median	Mean	N	n	Range	Median	Mean
Tarwhine *Rhabdosargus sarba*	1	1	20	20	20.0	3	3	19 to 20	20	19.7
Trevally, Silver *Pseudocaranx dentex*	37	36	17 to 41	26	26.0	40	37	20 to 40	30	31.0
Whiting, Sand *Sillago ciliata*	51	39	23 to 40	27	27.6	656	581	9 to 42	28	28.7
Whiting, School *Sillago flindersi*	1	1	25	25	25.0	-	-	-	-	-

- no observations or measurements were made

* protected species

10. SURVEY PERSONNEL

The following table presents a list of persons who worked on either one or both surveys. Whilst all persons provided their time in a voluntary capacity, some were also affiliated with a local business or organised group. We again thank all of the following people for their valuable contributions to this project.

Name	Affiliation	Survey Year 1 1999/2000	Survey Year 2 2003/2004
Reg Annan	1	*	*
Leonie Beers	1	*	
Wayne Brockman	1		*
Warren Buchan	1	*	*
John Buckley	1	*	
Jan Bush	1	*	
Gary Carter	1		*
Peter Christie	1		*
Aileen Clifton	1	*	
Bob Dredge	1	*	*
Marilyn Dredge	1	*	
Keith Everett	1, 2	*	*
Freda Fischper	1		*
Noel Fletcher	1	*	*
John Gale	1		*
David Greenhalgh	1, 2	*	*
Jim Hamburger	1		*
Peter Hay	1	*	
Renee Hooke	1, 3	*	
Robert Hooke	1, 3	*	
Hamish Hooke	1, 3	*	
Angus Hooke	1, 3	*	
Neville Horne	1	*	
Noreen Horne	1	*	
Geoff Howe	1	*	*
Geoff Howell	1, 6	*	*
Gloria Howell	1, 6	*	*
Eddie Hybler	1		*

List of survey personnel, continued.

Name	Affiliation	Survey Year 1 1999/2000	Survey Year 2 2003/2004
Olga Hybler	1		*
Elaine Jennings	1	*	*
Linda Jones	1		*
Bruce Jones	1		*
James Knight	1		*
Gabrielle Knight	1		*
Robert Knight	1, 6	*	
Alexis Knight	1, 6	*	
Jim Laing	1, 5	*	
Wal Lowder	1	*	
Barry McCormack	1	*	*
Bill McKinnie	1	*	*
Keith McKinnon	1	*	*
Bill Nelson	1		*
Terry O'Brien	1, 4		*
Debbie O'Brien	1, 4		*
Karl Smith	1		*
Danny Stolle	1		*
Barry Stubbs	1		*
John Turk	1		*
Peter Turner	1	*	
Carl Wilken	1	*	*
Carol Williams	1		*
Doug Williams	1		*
Gordon Winter	1, 2	*	*

* denotes participation in survey year 1 and/or survey year 2

Affiliation Key:

1 - Community Volunteer

2 - NSW DPI Fishcare Volunteer

3 - MacKenzie's Boatshed #

4 - O'Brien's Boatshed #

5 - Laing's Boatshed

6 - Tuross Lake Caravan Park

this boat hire business changed ownership between the two survey periods

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