ESTIMATION OF TOTAL CATCH OF SILVER KOB *ARGYROSOMUS INODORUS* BY RECREATIONAL SHORE-ANGLERS IN NAMIBIA USING A ROVING-ROVING CREEL SURVEY

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A statistical sampling method is described to estimate the annual catch of silver kob *Agryrosomus indorus* by recreational shore-anglers in Namibia. The method is based on the theory of progressive counts and on-site roving interviews of anglers, with catch counts and measurements at interception, using data taken during a survey from 1 October 1995 to 30 September 1996. Two different methods of estimating daily catch were tested by sampling the same population of anglers using a complete and an incomplete survey. The mean rate estimator, calculated by the ratio of the means with progressive angler counts and averaged fishing times, provides the best estimate of daily catch.

In order to provide advice on the sustainable utilization and management of a fishery, it is essential to assess the size of the stock and to predict major changes in it so that management options can be considered. A small fishery, such as that of the silver kob *Agryrosomus indorus* in Namibia, requires a simple but consistent assessment method, with minimum data input. The size of the Namibian kob stock has never been assessed. However, given the perceived decline in catches in recent years, it is essential to assess it in order to provide appropriate management advice. A basic data requirement for virtual population analysis (VPA) is the length distribution of the total annual catch (Sparre and Venema 1998). Such data are readily available for most conventional fisheries, because catches are logged and weighed when landed. However, recording such data is problematic when a fishery has a recreational component. In Namibia, kob are fished by three sectors: the commercial linefish-boat fishery, the commercial and the recreational ski-boat fishery and the recreational shore-angling fishery.

This study addresses the development and implementation of an operational method for assessing the number and length frequency of total landings by shore-anglers. Several incomplete assessments of shore-angling catches have been carried out in Namibia, but they estimated only part of the annual recreational catch. Using a census card method combined with an access method, Penrith and Loutit (1982) estimated that 1 740 kob (some 4 tons) were caught in Terrace Bay (Fig. 1) during 1980. Lenssen *et al*. (1991) also used an access survey design to estimate that 64 822 kob (some 65 tons) were removed during a survey period of 15 weeks (12 December 1989–28 March 1990) by shore-anglers along the Sandwich Harbour coastline (Fig. 1). The objective of this study is to establish the magnitude of catches by shore-anglers along the entire recreational area of the Namibian coast, and to compare this to catches by the commercial linefishing boats.

A roving-roving creel survey, in which the data are collected by interviewing anglers while they are fishing, is used in this study. This design (or a similar type) is often applied to estimate catch and effort for diffuse-access fisheries, where access-point surveys are not possible (e.g. Pollock *et al*. 1994, 1997, Hoenig *et al*. 1997).

In creel survey methods based on progressive counts, the total catch is obtained as the product of total effort and catch rate. The controversy over the proper procedure for estimating the overall catch rate (see Pollock *et al*. 1997) is addressed here by presenting different methods. The application and accuracy of these methods are compared with realistic values, obtained by conducting a complete survey (road-block) in an area with a defined access site. Problems in estimating recreational catches, including length of stay bias (Lucas 1963), are discussed from the perspective of improving the management of shore fisheries.

MATERIAL AND METHODS

The survey was carried out between 1 October 1995 and 30 September 1996. All commercial catches of kob were weighed and logged under the supervision

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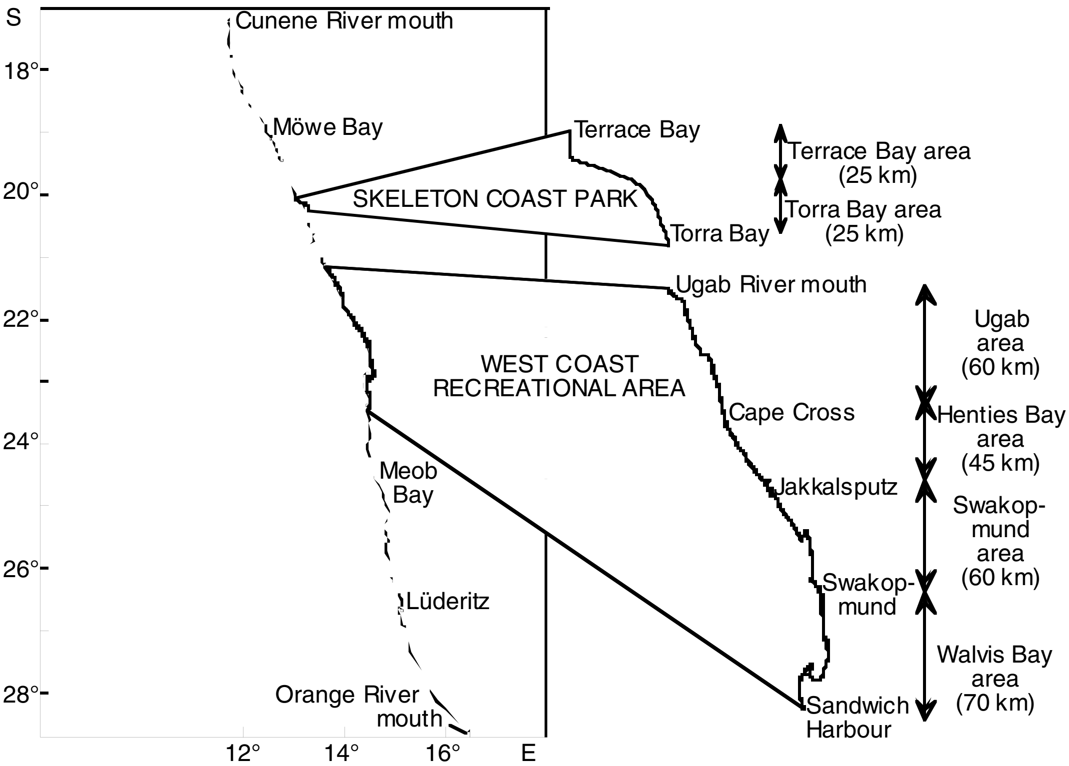

Fig. 1: Map of the Namibian coastline showing the two main recreational areas for shore-anglers (shaded) and the location and length of the subdivisions within them

of fisheries inspectors: at fish factories for linefish boats and at the fish-cleaning facilities in Swakopmund for commercial skiboats (Fig.1).

Study site

The 1 500 km of Namibian coastline extends between the Cunene and Orange rivers (Fig.1). A total of 1 105 km of coastline is closed to recreational fishing, whereas 85 km is partly closed or is under strict regulation. Only 310 km is completely open for recreational angling. However, linefish boats may operate along about 900 km of coastline. The area between the Orange River and Meob Bay (Fig. 1) is a diamond-mining area approximately 600 km long, which is closed to the public so shore-angling is limited. Because linefish boats and skiboats do not normally operate in the area, it was not included in this study. The coastline between Meob Bay and Sandwich Harbour, some 135 km long, is situated in the Namib-Naukluft Park. The Park is closed to the public, except the area around the Sandwich Harbour (30 km long), where entry is controlled by a permit system. Although this entire area is open to linefish boats and skiboats, the area is seldom fished. The Sandwich Harbour area is closed annually to shore-anglers between 25 January and 31 April, during the kob breeding season.

The coastline of the West Coast Recreational Area (between Sandwich Harbour and the Ugab River) is approximately 325 km long and is the only area open to the public throughout the entire year, with the exception of the Cape Cross Seal Reserve (15 km). Shore-angling and skiboat fishing take place in the West Coast Recreational Area, but linefish boats only occasionally fish there. The coastline between Ugab River and the Cunene River (515 km) is part of the Skeleton Coast Park and most of the linefish boat fishing takes place there. There are three inhabited

Table I: Strata names and symbols of the beach-survey sampling are listed. The sample size (n_h) was determined using optimum and proportional allocation (see text for details) by incorporating the number of days open for fishing (N_h) and the variance of the estimated catch per stratum. The actual 1995/96 sample size was used in this study (1 October 1995 to 30 September 1996)

Stratum number	Stratum	Symbol	Variance of catch × 1000	N_h	Sample size (n_h, days)		
					Optimum	Proportional	Actual 1995/96
1	Walvis Bay normal	W_n	0.04	349	1	24	8
2	Walvis Bay running	W_r	14.71	17	1	1	4
3	Swakopmund holidays	S_{ho}	37.91	90	8	6	21
4	Swakopmund non-holidays	S_{nho}	6.46	123	2	9	9
5	Henties Bay holidays	H_{ho}	130.33	90	26	6	15
6	Henties Bay non-holidays	H_{nho}	16.29	123	4	9	7
7	Ugab holidays	U_{ho}	343.17	90	67	6	17
8	Ugab non-holidays	U_{nho}	22.99	123	6	9	10
9	Torra Bay	T_o	70.68	62	10	4	4
10	Terrace Bay	T_e	2.17	366	2	26	10
11	Ugab off-season	U_{os}	1.05	153	1	11	9
12	Swakopmund off-season	S_{os}	8.54	153	3	11	9
13	Henties Bay off-season	H_{os}	3.82	153	1	11	9
Total					132	133	132

areas along that coastline (Fig. 1): Torra Bay, which is open to the public for only two months of the year (1 December – 31 January); Terrace Bay, which is open throughout the year, but can only accommodate a maximum of 40 visitors at any one time; and Möwe Bay, which is closed to the public.

Stratification

For the purpose of this study, the Namibian coastline (for recreational shore-angling) was divided into two regions; the West Coast Recreational Area and the Skeleton Coast Park (Fig. 1). Because of the differences in fishing effort within the two areas, the West Coast Recreational Area was subdivided into four areas and the Skeleton Coast Park into two (Fig. 1). Because anglers are more active during holidays and weekends than during weekdays and more active in summer than in winter, temporal stratification was necessary. "In-season" (*s*) was divided into "holiday" (*ho*) and "non-holiday" (*nho*). "Off-season" (*os*) was not subdivided, because the daily catch was small relative to the "in-season" daily catch. Stratum (*ho*) included weekends and public holidays, including the two weeks over Christmas. Stratum (*nho*) included all remaining weekdays (Table I).

The Walvis Bay area was divided into two time-periods: normal period (*Wn*), and the running period (*Wr*), when kob were spawning. This stratification was subject to annual change, because the spawning period changed each year. A total of 13 strata (*h*) was identified (Table I).

Survey technique

The principle of the roving-roving creel survey is shown in Figure 2. Two interviewees started the survey (usually at 10:00) at a selected site of a randomly, pre-assigned area. They travelled by vehicle at around constant speed, counting and interviewing anglers who were fishing. Interception of anglers before their catches were complete led to an incomplete measurement of catch. On average, anglers were interviewed when they had been fishing for only half of their total fishing time (L_i). Consequently, recorded catches were multiplied by a factor of two.

On reaching a group of anglers, their numbers were counted (A_i) and the time spent fishing was noted. The fish caught collectively by the group were sorted into species, then counted (c_i) and measured. For various reasons, it was not always possible to interview all the fishing groups observed on the beach. Where possible, all anglers were counted and those not interviewed were recorded as such. Passing vehicles were noted for the presence of anglers by counting the number of rods with reels visible. If rods could not be counted, then three anglers were allocated per light truck and one angler per car. Care was taken not to influence the interviewer by providing information on fishing conditions elsewhere. Random sampling

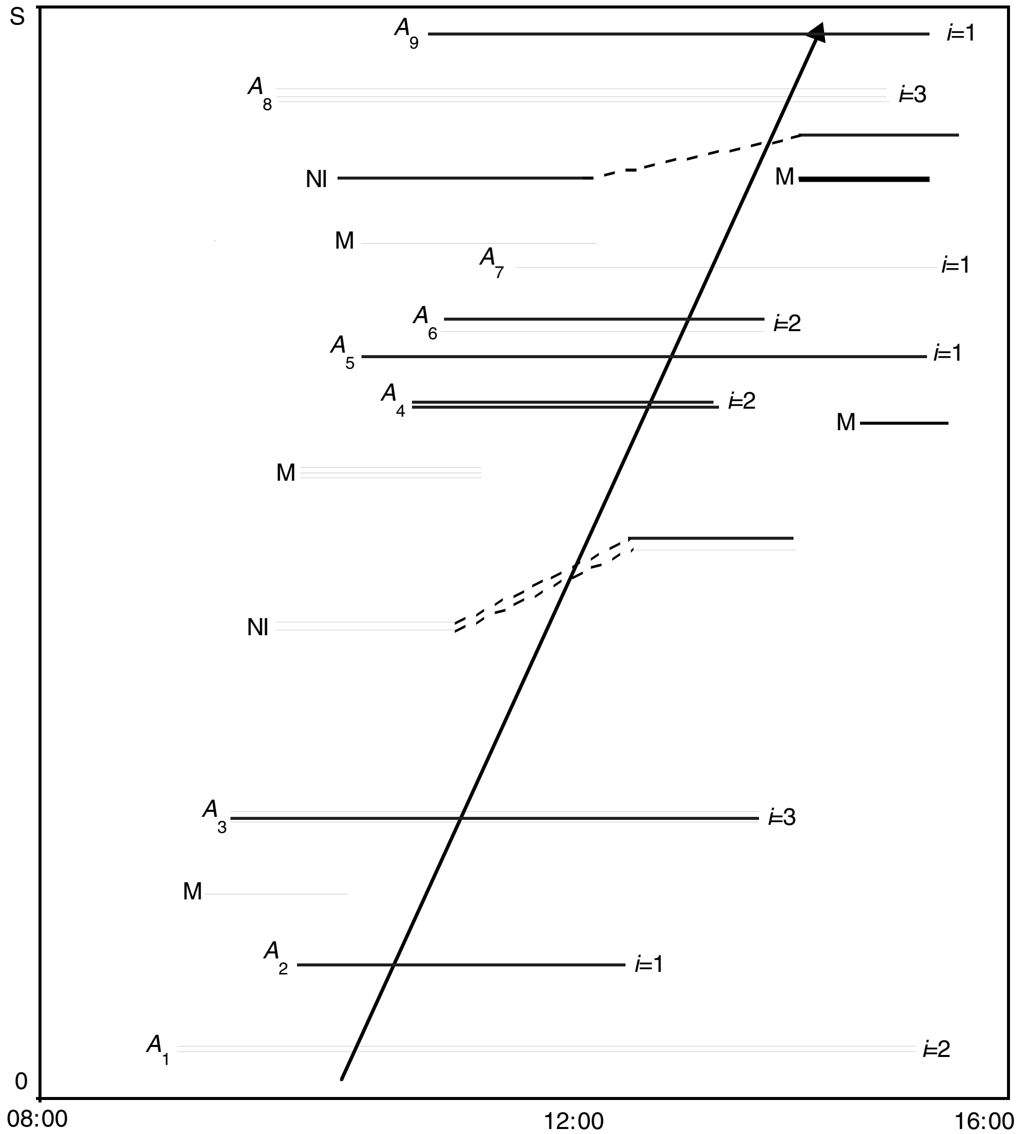

Fig. 2: A hypothetical roving survey graph for time of day versus distance along the stretch of beach surveyed (0 – S). The solid diagonal arrow represents the survey agent starting to survey at one end of the beach at approximately 10:00 and completing the survey of this area at around 14:00. The length of the lines on the chart indicate the length of stay of individual anglers, or group of anglers; three dotted lines represent a group of three anglers. The straight dotted lines represent stationary anglers who were intercepted and interviewed during the survey, whereas the inflected dotted lines (NI) denote those anglers that were counted but not interviewed. The solid lines (M) represent the anglers who were missed, the number of which is unknown to the survey. In this example, a total of nine groups (*A*) of anglers (*i*) were interviewed. A total of 26 anglers were fishing during that day. Of these, three were counted, but not interviewed, and seven were missed (adapted from Hoenig *et al.* 1993)

(without replacement) was used for sampling each stratum.

Sampling criteria

A total of 132 days (B) was scheduled for beach surveys per year. The days (referred to as sample size n_h in Table I) were allocated to the 13 strata, according to the following criteria (in order of priority):

(i) budgetary constraints;
(ii) the variance of the catch [var($\hat{\bar{c}}_h$)], which was determined from a three-month trial sampling period (see Table I);
(iii) the number of days in the stratum N_h (see Table I);
(iv) at least four surveys must be done in each stratum.

The number of sampling days was allocated to each stratum by simple proportional allocation (Equation 1), or by optimum allocation (Equation 2). Proportional allocation is only dependent on the length of period (N_h), whereas optimum allocation also considers the variance of the estimated average daily catch ($\hat{\bar{c}}_i$) per stratum.

$$n_{h\ prop} = B \times \frac{N_h}{N_{total}} \tag{1}$$

$$n_{h\ opt} = B \times N_h \times SD(\hat{\bar{c}}_i) / \sum (N_i \times SD(\hat{\bar{c}}_i)) \quad , \tag{2}$$

where c_i denotes the catch on day i.

Methods for estimating daily catch in the roving-roving surveys

The basic formula for estimating catch, according to Pollock *et al.* (1994), is

$$\hat{c} = \hat{A} \times \hat{\bar{T}} \times \hat{R} \quad , \tag{3}$$

where $\hat{A}$ is the total number of anglers encountered, considered here to be either the complete daily count or the instantaneous count of anglers. The estimated mean trip length ($\hat{\bar{T}}$) is calculated either from Equation 4 (in the case where $\hat{A}$ is assumed to be the complete daily count) or as a constant (in the case where $\hat{A}$ is considered as an instantaneous count). The estimated catch rate ($\hat{R}$) is determined either from the ratio of means $\hat{R}_1$ (Equation 5) or from the mean of ratios $\hat{R}_2$ (Equation 6).

On the assumption that all anglers were counted, $\hat{\bar{T}}$ is calculated as

$$\hat{\bar{T}} = 2 \left(\sum_{i=1}^{g} A_i L_i \right) \Big/ \sum_{i=1}^{g} A_i \quad , \tag{4}$$

where g is the number of angling groups (or parties) interviewed during a particular fishing day (at the stratum in question), A_i is the number of anglers in group i and L_i is the time spent fishing until interception (see Fig. 2). It should be noted that $\hat{A}$ exceeds $\sum_{i=1}^{g} A_i$ by the number of anglers counted but not interviewed.

The catch rate was estimated, by the ratio of means estimator:

$$\hat{R}_1 = \sum_{i}^{g} c_i \Big/ \left(\sum_{i=1}^{g} A_i L_i \right) \quad , \tag{5}$$

where c_i is the number of fish caught by angling-group i with an effort of $A_i L_i$ angling hours.

An alternative method for estimating the catch rate is the mean of ratios estimator (see Pollock *et al.* 1994, 1997, Hoenig *et al.* 1997):

$$\hat{R}_2 = (1/g) \sum_{i=1}^{g} \left(c_i / (A_i L_i) \right) \quad . \tag{6}$$

For this study, $\hat{R}_2$ was calculated without truncation (Hoenig *et al.* 1997), because "groups of anglers" were interviewed and normally their combined fishing time was longer than 30 minutes.

By substituting $\hat{\bar{T}}$ (Equation 4) and $\hat{R}_2$ (Equation 5) in Equation 3, the catch equation becomes more simplified:

$$\hat{c} = 2 \left(\hat{A} \Big/ \sum_{i=1}^{g} A_i \right) \sum_{i=1}^{g} c_i \quad , \tag{7}$$

i.e. the daily catch is obtained by doubling the total catch recorded from the anglers interviewed to the expected total for all anglers counted. Often, progressive counts of anglers (A) are considered instantaneous (Methods 3 and 4, see below), in which case T equals the number of hours in a fishing day (Hoenig *et al.* 1993, Pollock *et al.* 1994). A period of 12 h of daylight was used in the present study.

The following methods were used to estimate daily catches:

Method 1: $c = A \times T \times R_1$ (see Equation 7)
Method 2: $c = A \times T \times R_2$
Method 3: $c = A \times 12 \times R_1$ (Method 1 modified)
Method 4: $c = A \times 12 \times R_2$ (Method 2 modified)

Access-point survey

The performance of these four methods for calcu-

Table II: Daily catch for four surveys obtained by the complete and incomplete survey. The values for the incomplete surveys were estimated by four different methods. The slopes and r^2 values of the regressions are also given

Survey number	Daily catch (number of kob)				
	Complete survey	Incomplete survey			
		Method 1	Method 2	Method 3	Method 4
1	175	153	144	389	364
2	26	39	25	86	53
3	229	198	135	246	172
4	287	362	603	522	877
Slopes (r^2)		1.07 (0.88)	1.34 (0.57)	1.66 (0.70)	2.14 (0.57)

lating daily catches was tested against the true catches estimated from the access-point (complete) surveys. During four incomplete roving-roving creel surveys in the Ugab area (Stratum U_{nho}), which has a defined access site, a complete survey was done concurrently by setting up a roadblock. All vehicles entering and leaving the area were recorded. Catches of anglers leaving the area were inspected and their times of arrival and departure were recorded.

Pollock *et al.* (1997) suggested plotting the incomplete trip catch rates against the corresponding complete trip catch rates (r_1 v. r_2) for the validation of certain roving methods. In that case, a straight line should pass through the origin with a slope of unity. In the present study, for each method (1–4), the daily catch of the complete survey was plotted against the daily catch of the incomplete survey, and a straight line was forced through the origin. This comparison of the regression model adequacy measure (r^2) among the four methods gives an indication of which method should be used in future.

RESULTS

Incomplete v. complete survey study

Table II shows that Method 1 provided the best estimate of the real daily catch ($r^2 = 0.88$). The strong regression obtained using Method 1 indicates that the underestimate as a result of anglers that were missed may have been compensated by the possible overestimate in fishing time (see discussion below of length-of-stay biased sampling). The results of the incomplete-complete survey study (Table II) further showed that

Table III: Number of sampling days (n), mean daily catch and estimated annual catch of kob per stratum, using Method 1. Data collected from 11 600 anglers

Stratum	n	Mean daily catch[a] ± SE[b]	Estimated annual catch[c] ± SE[d] (× 1000)
Walvis Bay normal	8	10 ± 4	3.4 ± 1.3
Walvis Bay running	4	169 ± 84	2.9 ± 1.4
Swakopmund holidays	21	264 ± 53	23.8 ± 4.8
Swakopmund non-holidays	9	56 ± 23	6.9 ± 2.9
Henties Bay holidays	15	207 ± 64	18.7 ± 5.8
Henties Bay non-holidays	7	52 ± 30	6.4 ± 3.7
Ugab holidays	17	962 ± 289	86.6 ± 26.0
Ugab non-holidays	10	148 ± 39	18.2 ± 4.8
Torra Bay	4	442 ± 111	27.4 ± 6.9
Terrace Bay	10	39 ± 12	14.4 ± 4.3
Ugab off-season	9	37 ± 11	5.7 ± 1.6
Swakopmund off-season	9	55 ± 24	8.4 ± 3.6
Henties Bay off-season	9	48 ± 15	7.3 ± 2.3
Total	132		230[e] ± 12.7[f]

[a] $\hat{\bar{c}}(h) = \left[\sum_{n=1}^{n(h)} \hat{c}_n(h)\right] \Big/ n(h)$ using Method 1 (Equation 7) for $\hat{c}_n(h)$

[b] $SE(\hat{\bar{c}}(\mathrm{h})) = n^{-1/2} \left(\sum_{n=1}^{n(h)} [\hat{c}_n(h) - \hat{\bar{c}}(h)]^2 \Big/ (n(h)-1) \right)^{1/2}$

[c] $\hat{C}(h) = N_h \, \hat{\bar{c}}(h)$ with N_h from Table I

[d] $SE(\hat{C}(h)) = N_h \, SE(\hat{\bar{c}}(h))$

[e] $\hat{C} = \sum_{\mathrm{h}=1}^{13} \hat{C}_h$

[f] $SE(\hat{C}) = \left(\sum_{h=1}^{13} SE(\hat{C}(h))^2 \right)^{1/2}$

all methods used for estimating daily catch for incomplete surveys overestimated the real catch, but that the overestimation was slight for Method 1. By multiplying by N_h (the number of days of fishing per stratum), which in some cases could be up to 365 days, would result in serious overestimates of annual catches using Methods 2–4. Method 1 was selected because discrepancies were least between the results from this procedure and the true values.

Anglers seemed to be more successful in the first half of their fishing trip, which is one of the main reasons for the overestimation of the mean daily catch observed in this study (Table II). This was the result of implementing Method 1, which simply doubles the observed catches.

Estimation of catches using Method 1

Method 1 was used to estimate the daily catch per

Table IV: Average trip length obtained from incomplete and complete surveys. Survey 3 has been omitted because of insufficient data

Survey number	Average trip length (h)	
	Incomplete survey	Complete survey (*CV*)
1	5.09	7.05 (0.04)
2	5.56	6.72 (0.06)
4	8.12	7.85 (0.04)

Table V: Comparison of the catches and yields of three kob fisheries (1 October 1995 – 30 September 1996). Values for the skiboat and linefish boats were provided by the Ministry of Fisheries and Marine Resources, Namibia (unpublished data)

Fisheries	Numbers ± *SE* (×1 000)	Mass ± *SE* (tons)
Anglers	230 ± 13	361 ± 22
Skiboats	75 ± 4	97 ± 4
Linefish boats	219 ± 6	728 ± 22
Total	524 ± 15	1 187 ± 32

stratum for each sampling day (Table III). Despite stratification, the daily catches per stratum were variable. This can probably be attributable to varying environmental conditions. For example, during poor conditions, such as rough sea, sulphur eruptions and brown water, catch rates of kob were low.

The highest average daily catch of 962 (± 289) was in the Ugab area during the holiday season, more than twice that of the second highest catch of 422 (± 111) at Torra Bay (Table III). The annual catch in Terrace Bay was relatively low, probably as a result of the limit placed on the number of visitors there (maximum 40), of whom only about half were anglers. As expected, catches were generally low in all areas during the off-season.

Length-of-stay bias

A problem in roving surveys is in obtaining an unbiased estimate of the average length of completed trips (angler effort), commonly referred to as the "length-of-stay bias" (Lucas 1963). This problem arises when anglers are encountered and interviewed while they are fishing. Anglers fishing for a long time are therefore more likely to be encountered than those fishing for a short time. This implies that the average length of a fishing day (complete trips for all anglers) will be generally shorter than twice the average interrupted fishing day at interception (incomplete trips for interviewed anglers).

The importance of the length-of-stay bias was tested on the bases of information obtained from the complete-incomplete surveys. The length of the fishing trip was underestimated for Surveys 1 and 2, but was estimated fairly accurately for Survey 4 (Table IV). The length of trip of a shore-angler depends on various factors, e.g. tide, weather and catch of other anglers. The *CV*s of the average encountered length of trip determined by the complete surveys are very low (Table IV), indicating that the length-of-stay bias was not important in the present survey design.

Shore-anglers harvested approximately the same number of kob as did the commercial linefish boats (Table V). However, the yield by mass was much lower for shore-anglers. Catch by skiboats was small in comparison to the other two fisheries.

DISCUSSION

The survey design is based on three assumptions, which may not be entirely realistic. The total daily catch is calculated on the premise that all anglers are counted, and that the average catch rate within a stratum for a particular sampling day (as determined for the incomplete trip up to the time of interview) gives an unbiased estimate of the catch rate for the complete trip. Another assumption is that the catch rate calculated from the interviewed anglers is representative of the anglers who were not interviewed.

The assumption here that all anglers are counted on a particular day differs from the method of Pollock *et al*. (1994), who described the use of instantaneous and progressive counts (i.e. only a fraction of the total daily anglers are counted) in situations of random arrival during the entire fishing day. In Namibia, many angling areas are remote, so anglers generally fish for the entire day, and the chance of interception is good. This assumption was tested in the complete-incomplete survey, which indicated that some anglers could be missed in the incomplete surveys. Based on information from 452 anglers, some 89% arrived to fish before 10:00 and 97% before 12:00. Information based on 604 anglers showed that 88% were still fishing at 14:00 and 64% at 16:00. Therefore, arrival is not randomly spread over the entire day, and most anglers were present at noon. Nevertheless, some anglers could be missed during an incomplete survey, which would result in an underestimation of daily catch.

However, the mean daily catch was underestimated in only two of the four surveys (Table II).

The controversy concerning the most reliable procedure for estimating the overall catch rate is not yet resolved (see Pollock *et al*. 1997). The confusion stems from the correct procedure of averaging, i.e. whether the ratio of the means should be used (e.g. Neuhold and Lu 1957, Von Geldern and Tomlinson 1973, Malvestuto *et al*. 1978, Dent and Wagner 1991, Orsatti *et al*. 1991, Phippen and Bergersen 1991) or the mean of the ratios of individual catches and efforts be used (e.g. Hayne 1991, Hoenig *et al*. 1997, Pollock *et al*. 1997). The ratio of the means estimator ($\hat{R}_1$) is preferred in the present study, because the mean of the ratios ($\hat{R}_2$) is considered incorrect for fishing in the marine environment. Using ($\hat{R}_2$) implies that, irrespective of how long a group was fishing, their contribution to the estimated daily catch rate would carry the same weight. However, catch estimates of fishing parties with long fishing times should be considered to be more realistic than those with short fishing times, because the longer the fishing time the more chance that the estimated catch will equal the true catch of the day. Alternatively, if the assumption is made that the catch rate is constant and only dependent on the skill of the angler (e.g. lake fishing), then the mean ($\hat{R}_2$) may be the better estimator. However, in the present case, the catch rate depends on environmental factors and the skill of the anglers. By taking the ratio of the means, all these factors are incorporated.

Most creel census methods have shortcomings. However, in developing a sampling design, emphasis must be given to the feasibility and simplicity of the design, while achieving the required precision in the estimate of the harvest. By using simple principles and sound statistics an estimate of the annual harvest can be obtained, but it would be accompanied by a high variance. Attempts to decrease this variance might result in a complex design that could render the study economically non-feasible. The requirement should, therefore, influence the type of sampling design chosen. The aim of this study was to obtain an estimate of the catch by fish length (with its variance) as input data for a cohort analysis of the kob stock in Namibia. The method used is considered to be adequate for that purpose.

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