Preliminary estimates based on 2004 PIT tag recoveries

William G. Clark and Din G. Chen

Abstract

Recoveries in 2004 of tagged fish released in 2003 indicate harvest rates similar to those estimated by the analytical stock assessment in Areas 2B and 2C, much lower in Area 3A, and almost nil in Areas 3B and 4. There was little migration out of Area 2B, but elsewhere 10-20% of legal-sized fish moved from the area of release to another area.

Background

As part of the 2003 coastwide setline survey, the Commission staff released some 44,000 halibut injected with passive integrated transponder (PIT) tags (Kaimmer and Geernaert 2004, Chen 2004). In 2003 and 2004 IPHC scan samplers in ports throughout the Commission area have scanned over a million landed halibut and have recovered several hundred tags.

The primary purpose of this large project is to estimate the harvest rate of fully selected halibut by the commercial fishery, but the mark recaptures also permit estimates of length-specific selectivity schedules and rates of migration between areas. This paper reports preliminary estimates based on recoveries in 2004. (Recoveries in 2003 were too few to be useful.)

Raw data

Of the almost 29,000 legal-sized fish released in 2003, a total of 383 were recovered from commercial landings in 2004 . The great majority of recoveries were made in the area of release, but there was some movement among areas (Table 1).

Recovery rates were expected to vary with length and they did, but not in the expected fashion. The staff has generally assumed that vulnerability to capture (selectivity) is an asymptotic function of length, meaning that it increases with length up to some point and then remains constant. But in Areas 2B and 2C recovery rates increased with length to a maximum at about 110 cm and then declined (Table 2, Fig. 1a). In Area 3A recovery rates increased with length over the entire length range (Fig. 2b). Most surprising was the pattern in Areas 3B and 4, where recovery rates were highest among small fish and very few large fish were recovered (Fig. 2c).

These unexpected patterns prompted a re-analysis of the many marking experiments carried out by the Commission in the 1960s through 1980s (Clark 2005). While not usable for estimating exploitation rates, these data can be used to estimate selectivity, and they in fact showed patterns in Area 2 and 3A quite similar to what we are seeing in the 2004 PIT tag recoveries, so in this analysis selectivity was not required to be asymptotic. There are very few historical marking data from Areas 3B and 4 but what few there are (from Area 3B) show a pattern similar to Area 3A; i.e. increasing selectivity with length rather than decreasing as in the 2004 recovery rates.

Recovery model, point estimates, and variances

The number and distribution of tag recoveries depends on a number of factors. If Rec_{ijl} is the number of recoveries of fish in length interval *l* released in area *i* and recovered in area *j*, then the expected number is:

$$E\left(Rec_{ijl}\right) = Rel_{il} \cdot Surv_{il} \cdot Mig_{ij} \cdot HR_j \cdot Sel_{jl} \cdot SR_j \cdot DR$$

where

Rel_{il} = the number of releases in area *i* of fish in length interval *l*

$Surv_{il}$ = survival rate from 2003 to 2004 of releases in area *i* in length interval *l*

Mig_{ij} = migration rate from area *i* to area *j*

HR_j = harvest rate in area *j* of fish with selectivity = 1

Sel_{jl} = selectivity in area *j* of fish in length interval *l*

SR_j = sampling rate in area *j* (proportion of landed fish that were scanned)

DR = detection rate (proportion of tagged fish that were detected when scanned)

Survivorship from 2003 to 2004 could be calculated by accounting for recaptures in 2003 and natural mortality. Likewise the sampling rate was known and a working value of 90% was used for the detection rate. Migration rates, harvest rates, and selectivities were estimated by numerically locating the fit of the recovery model to the observed recoveries that maximized the binomial likelihood of the observed recoveries. Because of very low recoveries, Area 4 was treated as a unit, and no estimates were attempted for Area 2A.

To fix the scaling of the selectivities and harvest rate in each area, selectivity was defined to be one for fish in the 100-109 cm length interval at release, so values greater than one could occur. (When selectivity is known or assumed to be asymptotic, it is set to one for the largest fish, and that is the maximum.) A single selectivity schedule was estimated for Area 2B and 2C because the empirical schedules were very similar; likewise for Areas 3B and 4.

Variances were estimated by bootstrapping the data, i.e. drawing many random samples of size 29,000 by sampling the release/recovery data with replacement and computing the estimates for each sample.

Table 3 shows the estimates and standard deviations of harvest rate by length interval ($HR_j \cdot Sel_{jl}$), and Table 4 the estimates and standard deviations of migration rates (Mig_{ij}).

Comparison with analytical estimates of harvest rates

The annual stock assessment also estimates harvest rates as a function of length, so these can be compared directly with the mark-recapture estimates (Table 5 and Fig. 2). The assessment estimates shown here were located with a version of the model that fits an empirical rather than the usual asymptotic selectivity schedule. The error bars on the assessment estimates were calculated using a coefficient of variation of 15%, consistent with recent performance.

In Areas 2B and 2C both the level of harvest rates and the pattern of variation with length are similar to the assessment. In Area 3A the pattern is similar but the mark-recapture level is only about half the assessment level, indicating about twice the abundance. In Areas 3B and 4

the harvest levels estimated from the tag recaptures is next to nil while the assessment shows harvest rates similar to the other areas.

References

Chen, D.G. 2004. Preliminary analysis of the IPHC PIT tagging experiment in 2003. Int. Pac. Halibut Comm. Report of Assessment and Research Activities 2003:377-390.

Clark, W.G. 2005. Estimates of length-specific commercial selectivity from historical marking experiments. Int. Pac. Halibut Comm. Report of Assessment and Research Activities 2004 (this volume).

Forsberg, J.E. 2004. Portside sampling for recovered PIT tags in Pacific halibut. Int. Pac. Halibut Comm. Report of Assessment and Research Activities 2003:361-376.

Kaimmer, S.M., and Geernaert, T.O. 2004. 2003 PIT tagging: tagging equipment and protocol, and tag shedding studies. Int. Pac. Halibut Comm. Report of Assessment and Research Activities 2003:351-360.

Table 1. Releases of legal-sized fish in 2003 and recoveries in 2004, by area.

Area	Releases in 2003	Recoveries in 2004 by area								
		2A	2B	2C	3A	3B	4A	4B	4C	4D
2A	191	1	1	0	0	0	0	0	0	0
2B	1794	0	47	3	0	0	0	0	0	0
2C	2662	1	9	79	2	0	0	0	0	0
3A	11895	0	0	6	113	13	0	0	0	0
3B	9195	0	3	0	10	65	0	0	0	0
4A	2342	0	1	1	2	1	6	0	0	0
4B	916	0	0	1	0	0	0	1	0	0
4C	0	0	0	0	0	0	0	0	0	0
4D	867	0	0	0	0	0	0	0	0	0

Table 2. Releases of legal-sized fish in 2003 and recoveries in 2004, by area and length at release (e.g., "80" is 80-89 cm).

			Recoveries in 2004 by area							
Area	**Length**	**Releases**	**2A**	**2B**	**2C**	**3A**	**3B**	**4A**	**4B**	**4D**
2A	**80**	85	1	0	0	0	0	0	0	0
2A	**90**	42	0	0	0	0	0	0	0	0
2A	**100**	34	0	0	0	0	0	0	0	0
2A	**110**	13	0	1	0	0	0	0	0	0
2A	**120**	13	0	0	0	0	0	0	0	0
2A	**130**	4	0	0	0	0	0	0	0	0
2B	**80**	745	0	16	0	0	0	0	0	0
2B	**90**	371	0	11	0	0	0	0	0	0
2B	**100**	211	0	10	1	0	0	0	0	0
2B	**110**	178	0	4	1	0	0	0	0	0
2B	**120**	151	0	4	0	0	0	0	0	0
2B	**130**	138	0	2	1	0	0	0	0	0
2C	**80**	865	1	0	14	1	0	0	0	0
2C	**90**	538	0	3	17	0	0	0	0	0
2C	**100**	371	0	2	19	0	0	0	0	0
2C	**110**	302	0	2	11	0	0	0	0	0
2C	**120**	223	0	0	4	1	0	0	0	0
2C	**130**	363	0	2	14	0	0	0	0	0
3A	**80**	5219	0	0	1	10	6	0	0	0
3A	**90**	2938	0	0	2	29	4	0	0	0
3A	**100**	1583	0	0	3	26	2	0	0	0
3A	**110**	957	0	0	0	15	0	0	0	0
3A	**120**	550	0	0	0	14	0	0	0	0
3A	**130**	648	0	0	0	19	1	0	0	0
3B	**80**	3783	0	1	0	2	26	0	0	0
3B	**90**	2576	0	0	0	4	19	0	0	0
3B	**100**	1464	0	1	0	4	12	0	0	0
3B	**110**	744	0	1	0	0	5	0	0	0
3B	**120**	328	0	0	0	0	1	0	0	0
3B	**130**	300	0	0	0	0	2	0	0	0

Table 2 (cont'd.)

		Recoveries in 2004 by area								
Area	**Length**	**Releases**	**2A**	**2B**	**2C**	**3A**	**3B**	**4A**	**4B**	**4D**
4A	**80**	810	0	0	0	2	0	1	0	0
4A	**90**	610	0	0	0	0	1	5	0	0
4A	**100**	382	0	1	0	0	0	0	0	0
4A	**110**	237	0	0	1	0	0	0	0	0
4A	**120**	148	0	0	0	0	0	0	0	0
4A	**130**	155	0	0	0	0	0	0	0	0
4B	**80**	206	0	0	0	0	0	0	0	0
4B	**90**	270	0	0	0	0	0	0	0	0
4B	**100**	156	0	0	1	0	0	0	1	0
4B	**110**	100	0	0	0	0	0	0	0	0
4B	**120**	81	0	0	0	0	0	0	0	0
4B	**130**	103	0	0	0	0	0	0	0	0
4D	**80**	127	0	0	0	0	0	0	0	0
4D	**90**	191	0	0	0	0	0	0	0	0
4D	**100**	264	0	0	0	0	0	0	0	0
4D	**110**	149	0	0	0	0	0	0	0	0
4D	**120**	60	0	0	0	0	0	0	0	0
4D	**130**	76	0	0	0	0	0	0	0	0

Table 3. Estimates (± one standard deviation) of commercial harvest rates at length in 2004 based on PIT tag recoveries.

Length at release	Mean length in 2004	Area 2B	Area 2C	Area 3A	Area 3B	Area 4
80-89	88	0.06±0.01	0.08±0.01	0.01±0.00	0.02±0.00	0.01±0.00
90-99	98	0.11±0.02	0.14±0.03	0.04±0.01	0.03±0.01	0.01±0.00
100-109	108	0.20±0.04	0.25±0.04	0.06±0.01	0.03±0.01	0.01±0.00
110-119	118	0.14±0.03	0.17±0.04	0.05±0.01	0.02±0.01	0.00±0.00
120-129	128	0.07±0.03	0.09±0.03	0.09±0.02	0.01±0.01	0.00±0.00
130+	> 138	0.12±0.03	0.15±0.04	0.09±0.02	0.02±0.01	0.01±0.00

Table 4. Estimates (± one standard deviation) of migration rates.

	Probability of migrating from release area to:				
Release area	**Area 2B**	**Area 2C**	**Area 3A**	**Area 3B**	**Area 4**
Area 2B	0.95±0.03	0.05±0.03	0.00±0.00	0.00±0.00	0.00±0.00
Area 2C	0.11±0.04	0.84±0.05	0.05±0.04	0.00±0.00	0.00±0.00
Area 3A	0.00±0.00	0.02±0.01	0.84±0.04	0.14±0.04	0.00±0.00
Area 3B	0.01±0.01	0.00±0.00	0.10±0.03	0.89±0.03	0.00±0.00
Area 4	0.01±0.01	0.01±0.01	0.03±0.03	0.03±0.03	0.91±0.04

Table 5. Estimates of commercial harvest rate at length in 2004 from the 2004 stock assessment.

Mean length in 2004	**Area 2B**	**Area 2C**	**Area 3A**	**Area 3B**	**Area 4**
88	0.09	0.03	0.03	0.05	0.05
98	0.16	0.07	0.07	0.13	0.11
108	0.21	0.11	0.14	0.22	0.16
118	0.24	0.14	0.18	0.25	0.17
128	0.23	0.12	0.17	0.24	0.17
> 138	0.18	0.11	0.19	0.23	0.16

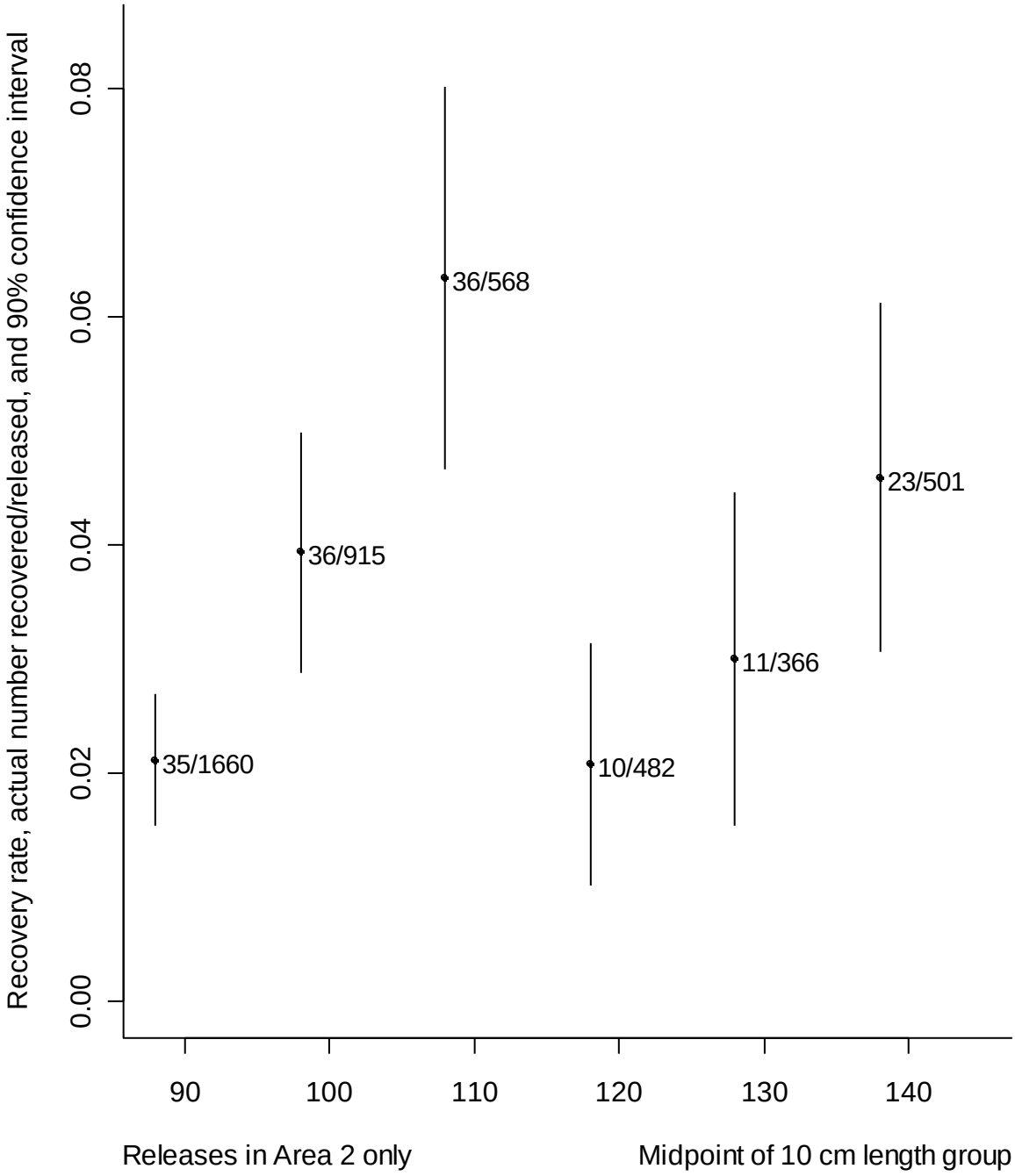

Figure 1a. Raw recovery rate as a function of length at release in Area 2 (2A, 2B, and 2C).

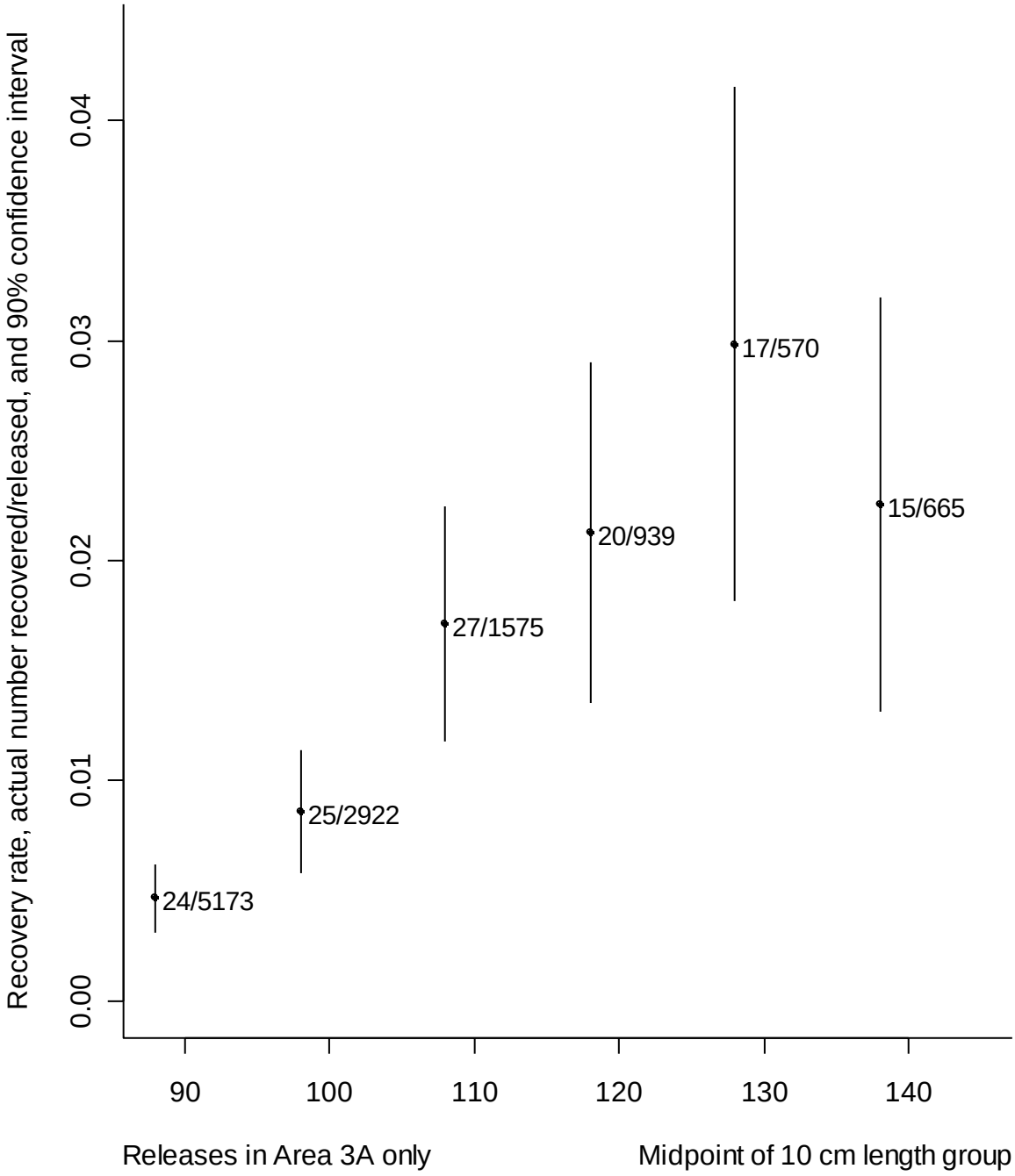

Figure 1b. Raw recovery rate as a function of length at release in Area 3A.

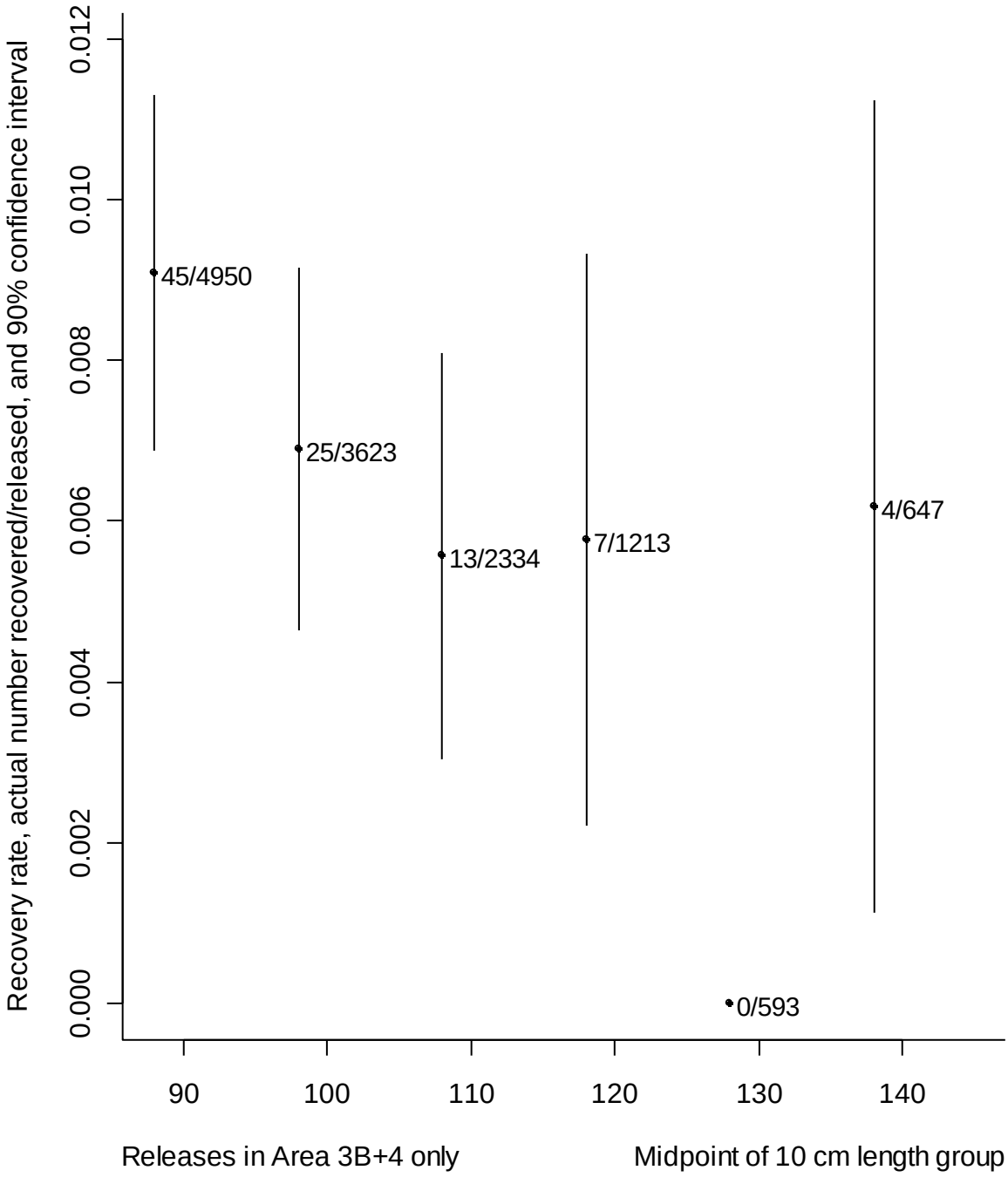

Figure 1c. Raw recovery rate as a function of length at release in Areas 3B and 4.

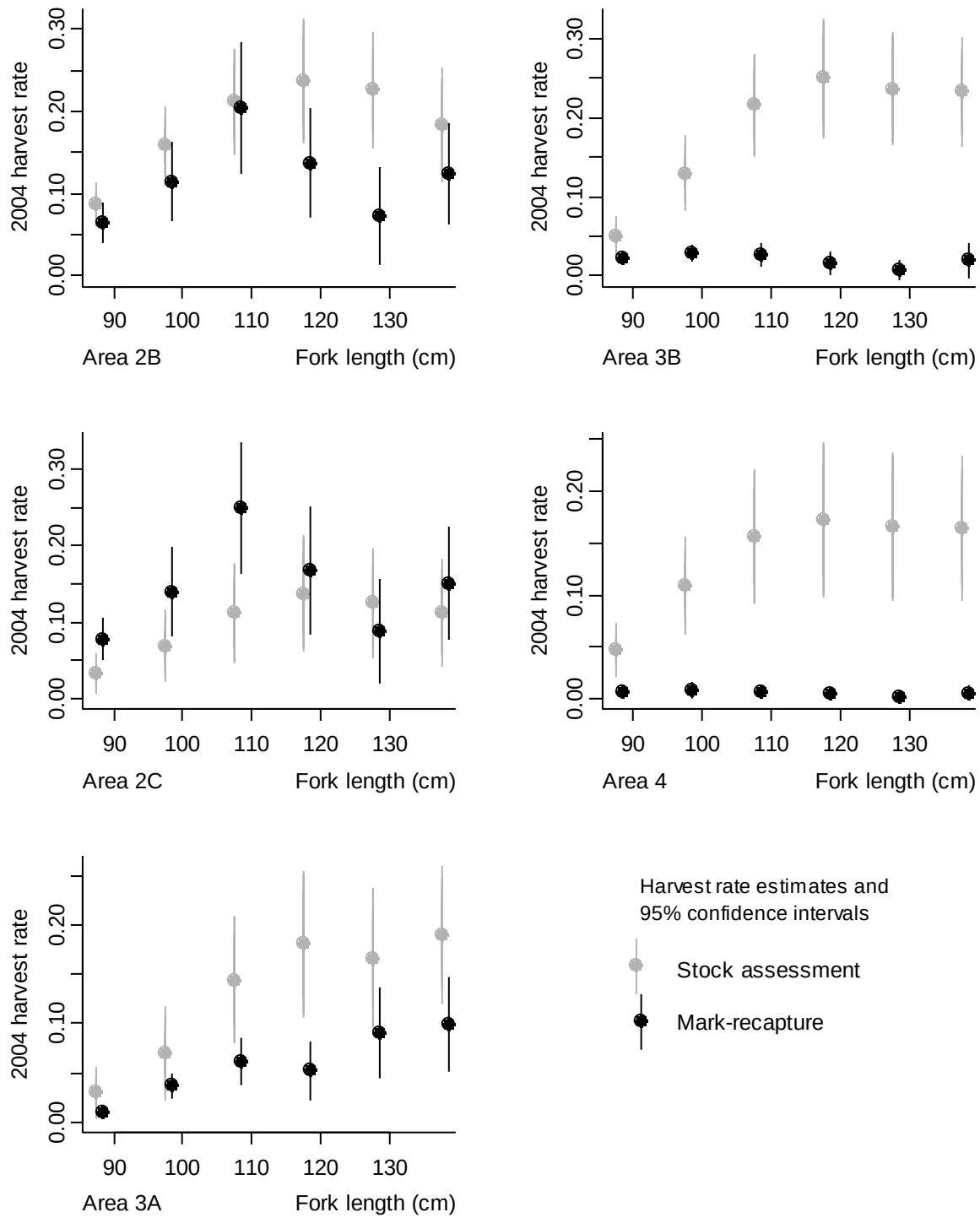

Figure 2. 2004 commercial harvest rates as estimated from the mark-recapture data and the analytical stock assessment.