Analysis of PIT tag recoveries through 2008

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Abstract

Patterns of tag-recoveries in 2008 were similar to 2007, with continued low recoveries in western areas and in Area 2B. A model was fitted this year that allowed for different migration rates for small and large fish, and this provided a better fit than one which assumed migration rates are the same for all fish. Patterns of recoveries and estimates of migration rates continue to show strong eastward movement of fish from Areas 4A and 3B, but less clear movement patterns from other areas.

Introduction

In 2003 the International Pacific Halibut Commission (IPHC) staff marked with PIT tags and released all fish caught on three skates of gear at all setline survey stations coastwide, totaling almost 44,000 fish (Kaimmer and Geernaert 2004). The release was repeated in 2004 in Areas 2B and 3A, totaling another 23,000 fish (Williams et al. 2005). In each year from 2003 to 2007, samplers in the ports scanned a substantial part of the landings to recover tags (Forsberg 2008).

The primary purpose of this large project is to estimate the harvest rate of fully selected halibut by the commercial fishery, but the tag-recovery data also permit estimates of length-specific selectivity schedules, rates of migration among regulatory areas, and, in principle, the rate of natural mortality.

This report updates the analyses of the PIT tag recovery data to include recoveries in 2008. Some alternative models were considered this year, including a model that allowed migration to depend on fish length, and for the first time, we included Area 4D in some models.

PIT tag recovery data for 2008

PIT tag recoveries for 2008 are discussed in detail in Forsberg (this volume). In total, 422 tags were recovered, with 261 from the 2003 releases and 161 from the 2004 releases (Table 1). Table 2 shows recoveries of tagged fish from the 2003 and 2004 releases in 2008 for comparison with the corresponding tables from previous years (Webster and Clark 2008). The overall pattern of recoveries is similar to 2007. In particular, very few 4A tags are now recovered in Area 4A, largely because the releases have now migrated eastward. Total Area 2B recoveries were again low compared to years prior to 2007, and are now comparable to recoveries of 4D tags, an area with similar scanning rates (Forsberg, this volume) but far fewer releases.

Tag-recovery modelling

The data are analysed by fitting tag-recovery models. For legal-sized fish, we adapt the migration models of Brownie et al. (1993) and Schwarz et al. (1993) to allow fishing mortality rates to vary with length. Natural mortality is fixed at a rate of 0.15, tag-loss is taken to be 3% per year, and based on previous seeding work, we assume 97% of scanned tags are detected. Other

sources of fishing mortality – sport catch, wastage, personal use and bycatch – are accounted for as components of total fishing mortality in the models.

We fitted a sequence of plausible models to the recovery data from Areas 2B-4A. Area 4D data was included in some additional modelling and is discussed below.

- Fishing mortality varies with length, and area, but not with year; migration rates are constant over time (FlaM).
- Fishing mortality varies with length, area, and year; migration rates are constant over time (FlayM);
- Fishing mortality varies with length, area, and year; migration rates are constant over time but a different for fish under 90 cm and with length greater than or equal to 90 cm, assuming a 3 cm/year growth rate since release (FlayMl);
- Fishing mortality varies with length, area and year; migration rates in the year following release differ from those in subsequent years (FlayMy).

In the FlayM, FlayMl, and FlayMy models, commercial fishing mortality, F, was allowed to vary by year through mortality of 100 cm fish. The models are parameterized so that fishing mortality at length l cm is a proportion (the selectivity), Sel_l, of fishing mortality of 100 cm fish, F_{100}:

$$F_l = F_{100} Sel_l .$$

In models that allow fishing mortality to vary with year, only F_{100} is allowed to vary. Under these models, the shape of the relationship of F with length stays the same over time, which avoids fitting models with extremely high numbers of fishing mortality parameters.

Models were selected using Akaike's Information Criterion (Akaike 1973), which is given by

$$AIC = -2\log(L) + 2p,$$

where L is the likelihood, and p the number of parameters. The first term decreases as the fit improves, while the second term is a penalty for model complexity. The "best" model of those being considered will have lowest the AIC. The values of ΔAIC show differences in AIC between a given model and best model.

Model	-2log(L)	parameters	AIC	ΔAIC
FlaM	2446.0	50	2546.0	69.4
FlayM	2357.4	70	2497.4	20.8
FlayMl	2309.9	90	2489.9	13.3
FlayMy	2296.6	90	2476.6	0.0

Of the fitted models, model FlayMy had the lowest AIC and was the best fitting model of those we considered. However, that the next best model, FlayMl, is an improvement over simpler models is also evidence that migration rates are different between large and small halibut. This implies that a model that allows both different migration rates among years and between the two size groups should be fitted. We have not fitted such a model: the data in some groups in each of the fitted models are already sparse, and estimation of standard errors (using parametric bootstrapping)

was somewhat unstable for some length groups, and we anticipate more problems in estimation from a more complex model.

Migration estimates from the best fitting model, FlayMy, were examined in Webster and Clark (2008), and do not differ greatly with the addition of data from 2008. This model was proposed after patterns in the raw recovery data implied that migration following the year of release was very small in Areas 3A, 2C, and 2B. The 2008 data continue to support this model. See Webster and Clark (2008) for a discussion.

The estimates we present are for model FlayMl, which estimates different migration rates for fish under and over 90 cm in length (Figs. 1 and 2). The migration estimates for Area 4A in particular differ greatly between the size groups, with much greater migration from Area 4A to Area 3A estimated for smaller fish, although the estimates for Area 4A fish under 90 cm are very imprecise due to sparse data. The estimate of the migration rate from Area 3B to Area 3A is also higher for smaller fish, but estimates for other areas are similar across the two groups. Although we estimate that a smaller proportion of fish larger than 90 cm migrate each year, estimated rates of up to 10% per area confirm that migration is ongoing for larger fish. This was also apparent in the raw data, with rates of tag recoveries out of the area of release showing movement of tagged fish across all release length classes (Table 3).

We also fitted some models to data that included releases and recoveries from Area 4D. In the first two years following releases, commercial fishing in Area 4D was concentrated around St Matthew Island. Because tags were released only on the Area 4D edge, almost no recoveries were made in this area in 2004 and 2005. From 2006, the distribution of fishing changed, with more commercial catch taken from the Area 4D edge. Consequently, tag recoveries have been higher from 2006 onwards, and recovery rates are now at least as high as those in eastern areas. From these analyses, we estimate an annual migration rate of 9% from 4D south to 4A, and a total rate of 1.7% to areas east of Area 3B. To date, there has been no recorded migration of tagged fish into 4D from other regulatory areas.

Estimates of commercial fishing mortality from model FlayMl are shown in Figure 2. Although this model provided a better fit than models which assumed no length differences in migration rates, for some areas there was little data in one or both length groups. This has led to some very high standard errors in estimates of commercial fishing mortality, particularly for smaller Area 4A fish. Thus, while we have evidence that migration rates depend on fish length, such a model does not always lead to meaningful estimates of fishing mortality.

Net migration

The tag-recovery modelling leads to estimates of annual rates of emigration from each regulatory area. We can estimate net annual migration by applying the migration estimates from the model to estimates of the number of legal-sized fish. Using population estimates from the 2008 stock assessment and the single migration matrix estimated under model FlayM above, we obtain the net migration rates shown in Table 4. We estimate strong net eastward migration from Area 4A is estimated, at a rate of 15% per year, while Area 2B receives the greatest percentage of migrants relative to its population, with an estimate of almost 7% annual inward migration. Other net migration estimates are smaller, with values reflecting a combination of emigration and immigration.

Discussion

Over the course of this study, recoveries of tagged fish out of release area have shown that migration is an ongoing process not restricted to small, younger fish. This is supported by the results of our tag-recovery modelling, which show continued migration of fish greater than 90 cm in length at estimated rates of up to 10% per year for each regulatory area. Rates of migration are estimated to be even greater for smaller fish in western areas. The recovery data are too sparse for most regulatory areas to permit a more detailed look at the relationship between halibut size and migration probability, but the raw data imply this relationship varies greatly among areas.

As in 2007, the best fitting model of those we considered was one which showed little or no movement of fish out of areas in the eastern Gulf of Alaska after the first year following releases of the tags. The 2008 data continue to show support for the possibility that while migration is an important and ongoing process eastward from Areas 4A and 3B, there is little or no migration from areas to the east.

Clark (2006) also estimated rates of net migration, but used model predictions of the 2004 tag distribution as measures of relative population sizes. This approach leads to a much higher estimate of net migration into Area 2B, largely due to Area 2B releases (and hence 2004 predicted numbers) accounting for a smaller proportion of the coastwide total than corresponding estimates of population size from the coastwide stock assessment.

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Table 1. Summary of PIT tag recoveries by release and recovery year

Year of release	Year of recovery						
	2003	2004	2005	2006	2007	2008	Total
2003	86	383	463	429	293	261	1,915
2004	0	45	297	251	193	161	947
Total	**86**	**428**	**760**	**680**	**486**	**422**	**2,862**

Table 2a. Recoveries in 2008 of fish released coastwide in 2003.

Area of release	Releases in 2003	Recoveries by area in 2008									
		4D	4C	4B	4A	3B	3A	2C	2B	2A	Total
4D	979	11	0	0	2	0	0	0	0	0	13
4B	1,128	0	0	0	0	0	2	1	0	0	3
4A	3,452	0	0	0	3	2	13	2	2	1	23
3B	15,282	0	0	0	0	43	41	6	1	1	92
3A	16,413	0	0	0	0	4	75	1	2	0	82
2C	3,675	0	0	0	0	0	1	26	1	0	28
2B	2,717	0	0	0	0	0	0	1	14	0	15
2A	299	0	0	0	0	0	0	0	3	2	5
Total	**43,945**	**11**	**0**	**0**	**5**	**49**	**132**	**37**	**23**	**4**	**261**

Table 2b. Recoveries in 2008 of fish released in Areas 2B and 3A in 2004.

Area of release	Releases in 2003	Recoveries by area in 2008									
		4D	4C	4B	4A	3B	3A	2C	2B	2A	Total
3A	20,341	0	0	0	0	8	136	3	0	0	147
2B	3085	0	0	0	0	0	1	0	12	1	14
Total	**23,426**	**0**	**0**	**0**	**0**	**8**	**137**	**3**	**12**	**1**	**161**

Table 3. Proportion of PIT tag recoveries made outside of the release area, by release area and length at release.

Length at release	Release Area						
	4D	4A	3B	3A	2C	2B	Coastwide
<81 cm	0.00*	0.79	0.36	0.19	0.28	0.02	0.27
81-100 cm	0.06	0.69	0.37	0.10	0.11	0.07	0.17
101-120 cm	0.23	0.67	0.39	0.08	0.11	0.10	0.16
>120 cm	0.25	0.25*	0.47	0.07	0.12	0.10	0.11

* Fewer than 10 recoveries

Table 4. Estimates of net annual migration rates (%) for legal-sized halibut.

Area	Emigration[1]	Immigration[2]	Net migration
4A	18.3	3.3	-15.0
3B	11.4	8.9	-2.5
3A	5.9	8.4	2.4
2C	10.1	6.0	-4.2
2B	1.8	8.6	6.8

[1]Estimates of mean annual emigration rates from tag-recovery modelling for 2004-08
[2]Based on legal-sized population numbers for January 1 2008 estimated using the coastwide stock assessment.

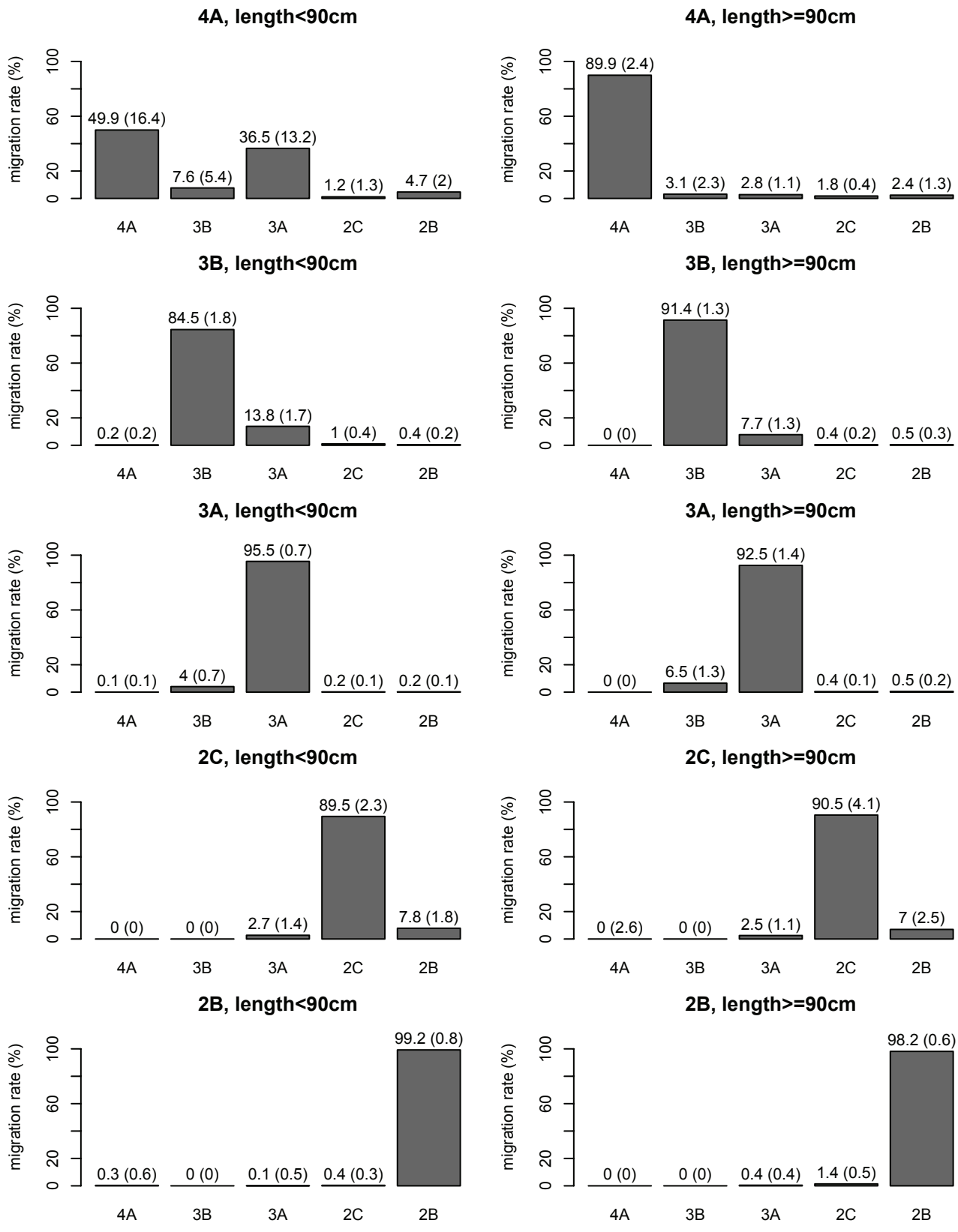

Figure 1. Estimated annual rates of migration from each regulatory area (rows) for fish with length under 90 cm, and for those with length greater than or equal to 90 cm.

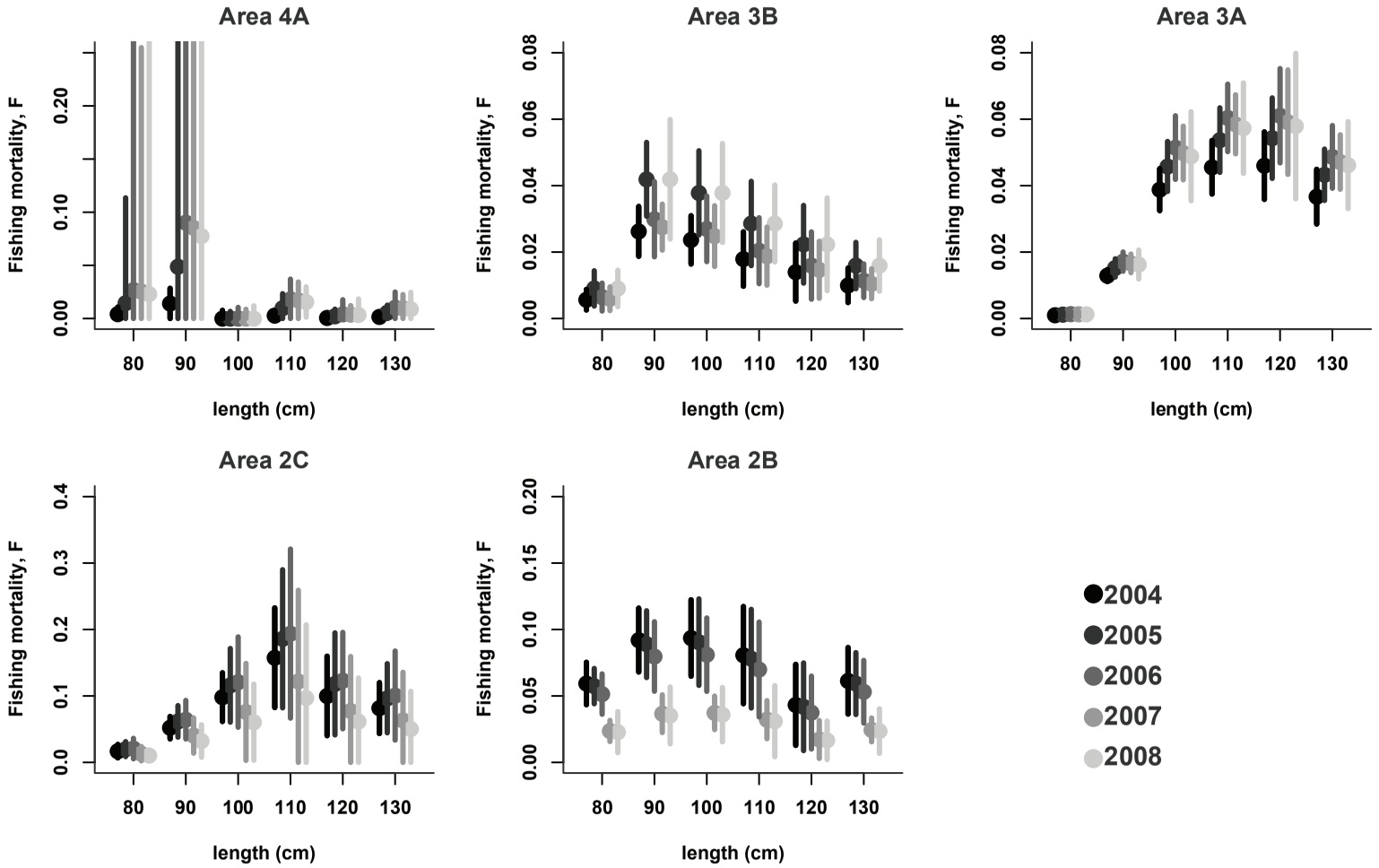

Figure 2. Estimated rates of commercial fishing mortality by regulatory area, length, and year from selected FlayMl model, along with approximate 95% confidence intervals. The rates shown are for 80, 90, 100, 110, 120 and 130 cm fish for all years.