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Red snapper otoliths selected for aging at NMFS Panama City Laboratory and discussion of future sampling targets

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Otoliths aged for 1999 assessment:

While there have been several red snapper growth studies that provided size-at-age estimates and growth curve parameters, additional annual information on direct age composition from otoliths is increasingly called for. As a result, expanded efforts in port collection of otoliths began in 1998 (see annual collection reports: Allman et al. 2000, Fitzhugh et al. 1999, Lombardi-Carlson et al. 2001, 2003, and Mikulas et al. 2002). It was also suggested that archived red snapper otoliths from prior years should be aged to generate annual age composition data sets (Reef Fish Stock Assessment Panel 1999).

During earlier red snapper assessments, the Goodyear probabilistic method was commonly used to generate catch-at-age from length data. This approach was also used in the last "full" assessment, but the resulting age compositions were additionally compared to age compositions based on empirical otolith aging results (Schirripa and Legault 1999). These empirical age compositions were derived from a 1998 data set from the Panama City Laboratory reflecting broader age sampling by gear and location and a from a dataset from Louisiana State University for the commercial handline west sector for 1995-1997 (Schirripa and Legault 1999).

Otolith collections archived:

Collections from federally sponsored sampling programs (including the Trip Interview Program, Beaufort Headboat Survey, Marine Recreational Fisheries Statistical Survey-MRFSS, and various scientific surveys) were archived at the Panama City Laboratory, largely beginning in 1991 and expanded in 1998 (see summary in Table 1). Before 1991, annual otolith collection efforts were minimal—the exception being 1980 (Table 1). Augmented by the large increase in collection efforts beginning in 1998, the total archived collection through 2002 is about 60,000 red snapper otoliths from about 5000 collections (Table 1).

In 1998, several sources contributed to the collection of red snapper otoliths but from 1999 onward, the TIP program provided the majority (Figure 1). As a result, most otoliths were taken from the commercial sector which is the main sector targeted by the

TIP program. Red snapper comprised a large share of the otoliths received at the Panama City Laboratory in 1998 and 1999 (Figure 2). From 2000 to 2002, other species were collected in increasing numbers while the numbers of red snapper declined somewhat (Figure 2). However, red snapper remains the largest component by species, of the annual otolith totals. For further breakdown, see annual collection reports (Allman et al. 2000, Fitzhugh et al. 1999, Lombardi-Carlson et al. 2001, 2003, and Mikulas et al. 2002).

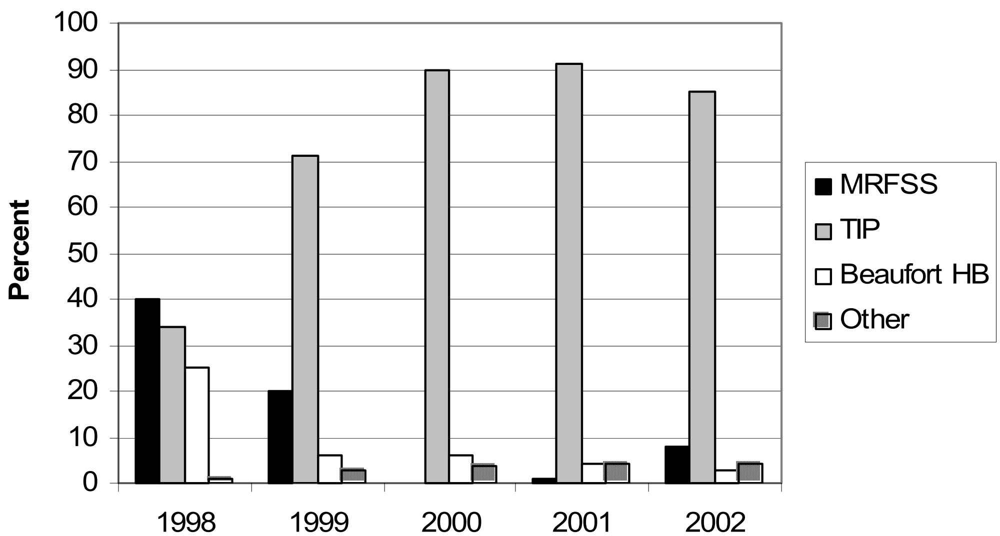

Figure 1. Percent of red snapper otoliths annually collected by the principal sampling programs. The category denoted as "other" primarily includes scientific survey samples.

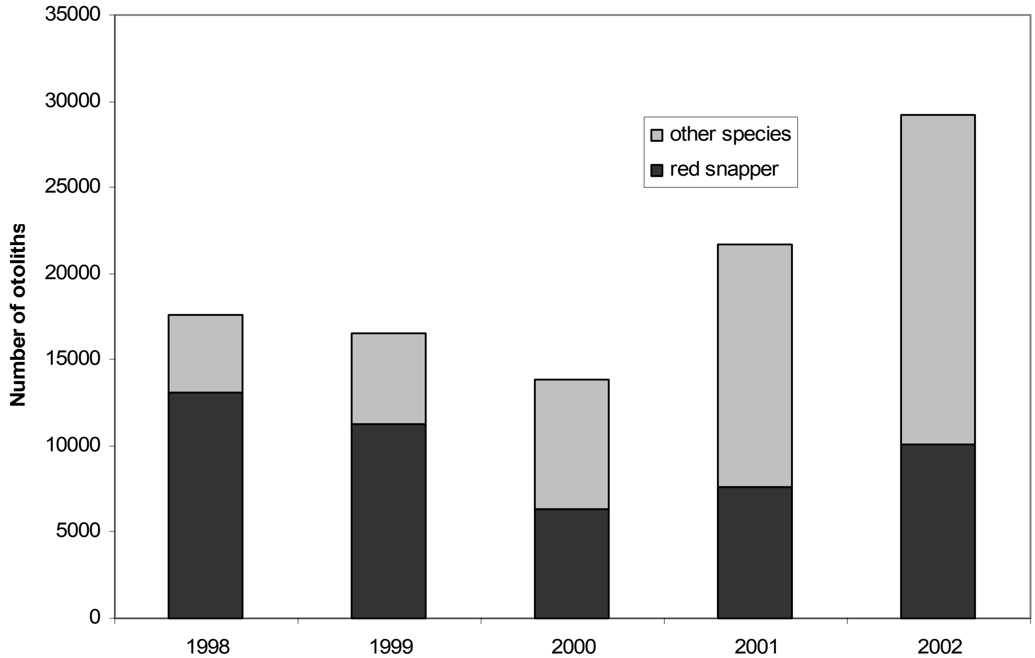

Figure 2. Annual numbers of otoliths from red snapper and from species other than red snapper, archived at Panama City since 1998. Total species represented: n=33 in 1998, n=31 in 1999, n=39 in 2000, n=61 in 2001 and n=55 in 2002. Besides red snapper, other species targeted for aging in the last five years include gag, red grouper, scamp, yellowedge grouper, vermilion snapper, yellowtail snapper, gray triggerfish, king- and Spanish mackerel.

Table 1. Summary of Gulf of Mexico red snapper otoliths archived and aged at the Panama City Laboratory. All red snapper otoliths must be sectioned to be aged. The category of whole otoliths remaining intact plus the category of sectioned otoliths yields the total number available from a particular year. The category "selected by fish size" includes otoliths selected for aging for different purposes including characterization of size-based reproductive traits and tournament-sampled fish. See text for criteria on selection of otolith samples for aging. The 2002 tally of 5,187 otoliths aged, includes 736 Florida recreational samples (originally received at Panama City) that will be included in the state share of the Fin Data base in the future.

Year	# of Whole Otoliths Remaining	# of sectioned otoliths	Total # of red snapper otoliths	Sub-Sampled for aging?	# sectioned aged that were considered selected for size	% Bias per year	# sectioned aged randomly
1980		339	339	No			339
1981	1		1				
1983	1		1				
1991		1,148	1,148	No	16	1	1,132
1992		1,369	1,369	No	22	2	1,347
1993	1,348	2,445	3,793	Yes		0	2,445
1994	659	1,894	2,553	Yes		0	1,894
1995		801	801	No	151	23	650
1996		238	238	No		0	238
1997		248	248	No	6	2	242
1998	7,916	5,212	13,128	Yes	883	20	4,329
1999	6,388	5,191	11,579	Yes	448	9	4,743
2000	3,089	3,783	6,872	Yes	16	0	3,767
2001	4,216	3,431	7,647	Yes	33	1	3,398
2002	4,800	5,335	10,135	Yes	148	3	5,187
Total	28,416	31,434	59,852		1,723	6	29,711

Otoliths selected for aging for next full assessment (scheduled 2004):

Beginning in 1998, there was a substantial increase in efforts to process and age red snapper at the Panama City Laboratory in line with the increase in port collections. However, in balance with other demands, including a need to continue processing previously archived red snapper otoliths, annual sub-sampling of red snapper otoliths was deemed necessary and, looking forward to the next full stock assessment, we developed a working strategy. Collections of biological samples (i.e., number of otoliths and gonads collected at each intercept as opposed to individual fish records) have been logged in as they have been received at the laboratory. After compiling collections at the end of each year, an annual sub-sample of otoliths was selected based on stratified random draws from the logged collections. In accordance with the red snapper fishery, approximately 50% of the collections were targeted for sub-sampling from the western gulf, and 50% from the eastern gulf. In addition, we attempted to randomly select collections that represented all fishing sectors as reflected in the landings (categorized as: private recreational, recreational charter boat, recreational headboat, commercial hook-and-line, and commercial longline). Ideally, this would have comprised a draw of about 50% recreational and 50% commercial samples for the overall Gulf of Mexico. Unfortunately, few recreational samples were available in comparison to commercial samples. In particular, commercial hook-and-line samples have dominated the red snapper otolith collections over the years (Allman et al. 2000, Fitzhugh et al. 1999, Lombardi-Carlson et al. 2001, 2003, and Mikulas et al. 2002). We set an annual target of about 4000 red snapper otoliths as a basis to then draw stratified sub-samples (1998-present). With this target, we could then achieve roughly equal representation between commercial and recreational sources and between eastern and western gulf regions each year (Table 2). From earlier years, we attempted to age all available otoliths, but subsamples from 1993 and 1994 collections were based largely on an effort to achieve parity in representation between the eastern and western gulf. Once collections were drawn, an annual database of the individual fish records was generated and the aging begun. At the completion of the annual aging session, ages were entered and the database was verified against original collection records (provided by port agents). In addition to these sub-samples representing port collections, red snapper otoliths from scientific surveys, particularly the NMFS Pascagoula long-line survey, were selected for aging.

Both random and size-selected red snapper otoliths were aged. However, for size and age characterization of each fishery only ages from randomly collected fish were used. Ages from size-selected fish, tournament fish and scientific-survey fish were included for size-based reproductive parameters and growth curve analysis. Typically, selected samples represent a low percentage of the total processed (about 5%, Table 1) but were higher in some years where there was a directed effort to obtain reproductive samples from larger-sized fish (e.g., 1998, Table 1).

Reconsideration of otolith targets within strata:

In September 2003, the available red snapper ages were reviewed and the SEFSC Sustainable Fisheries Division (SFD, Miami) recommended that processing and reading be maximized by the following stratification: year, 2-month wave (as defined by MRFSS sampling protocol), region (1-Texas, 2-Louisiana, and 3-eastern Gulf representing landings from Mississippi through West Florida) and mode. Modes represented were recreational—1-charterboat (CP), 2-head boat (HB), and 3-private boat (PR) (all hook-and-line) and commercial—4-commercial hook-and-line (HL) and 5-commercial long-line (LL). This effectively brings the total to 90 cells for the Gulf of Mexico each year and the potential for 1080 cells over the years 1991-2002 (Table 2). In that not all otoliths could be processed and read in the remaining time before the scheduled assessment, SFD recommended that at least 100 otoliths be read per stratum.

By processing and aging an additional 3249 otoliths between September 2003 and March 2004, we did meet the 100-per-cell criterion where possible, however, the results of Table 2 indicate that many of the possible cells (n=1080) remained empty based upon the available archived samples. In the commercial sector, the 100-per-cell criterion was met 61 times, largely during years 1999-2002 for the Louisiana and East regions. For the recreational sector, this objective was less often achievable as the 100-per-cell criterion was possible to meet 48 times (all years; Table 2). The criterion was only sporadically met during the earlier years, principally 1993-1994.

Table 2. Results of 100-per-cell objective of processing otoliths from an available archive. “Yes” means samples were processed and aged and “No” refers to unprocessed samples remaining within the archive. A. refers to recreational tallies and B. refers to commercial tallies.

A. Recreational

			Jan/Feb 1		Mar/Apr 2		May/June 3		July/Aug 4		Sept/Oct 5		Nov/Dec 6		Grand Total	Grand Total
Mode		Year	yes	no	yes	no	yes	no	yes	no	yes	no	yes	no	Yes	No
CP	EAST	1991			27		24		100		88		8		247	
		1992			65		74		97		81		39		356	
		1993			17		93		157		142		7		416	
		1994			37		133		170		112		30		482	
		1995			46		162		109		49				366	
		1996			4		78		20		2				104	
		1997							18		39				57	
		1998					110	22	313	1,220	442	2,403			865	3,645
		1999	36		100	195	220	429	264	708	74				694	1,332
		2000			129		264	1	69		47				509	1
		2001			100		142		93		78				413	
		2002			110		395		295		337		1		1,138	
	LA	1998					20		99	151	19				138	151
		1999			1				100	97					101	97
		2000							3						3	
	TX	1991							258		252		18		528	
		1992	207						218		62				487	
		1993							132		90				222	
HB	EAST	1991					11		9						20	
		1992			8		42		16		8		4		78	
		1993	10		49		101	11	71		19		26		276	11
		1994	15		36	22	61		70		90				272	22
		1995					9		2		1				12	
		1996					58		49		10				117	
		1997			1				22		52		24		99	
		1998	10		47		262	62	114	354	99	118			532	534
		1999	10		86		148	58	100	18	44	6			388	82
		2000					52		31		69				152	
		2001			1		37		112		73				223	
		2002			10		70		77		65				222	
	LA	1993	62		88		100	9	100	74	10		31		391	83
		1994	28		64	22	39		53		55				239	22
		1995					4						6		10	
		1998					36		40						76	
		1999	11		30		34		25						100	
		2000					92		77		31				200	
		2001					17		22		12				51	
		2002			5		24		21	1	18				68	1
	TX	1991			11				45		40		7		103	
		1992			3		1				22				26	
		1993	102	148	102	76	102	59	103	104	101	67	19		529	454
		1994	23				16		89		43		17		188	
		1998	22				319	295	127	903	24				492	1,198
		1999			90		66		18						174	
		2000			4		13		22		14				53	
		2001					5		18						23	
		2002			25		13		14		5				57	
PR	EAST	1992					1		1						2	
		1998							145		128	17			273	17
		1999					70		536	244	2				608	244
		2001			2										2	
		2002					22			1					22	1
	LA	1998					15		167		42				224	
		1999							82						82	
		2000					2		1						3	
	TX	1993							24						24	
		TOTAL	536	148	1,298	315	3,557	946	4,918	3,875	2,991	2,611	237		13,537	7,895

B. Commercial

Gear		Year	Jan/Feb 1 yes	no	Mar/Apr 2 yes	no	May/June 3 yes	no	July/Aug 4 yes	no	Sept/Oct 5 yes	no	Nov/Dec 6 yes	no	Grand Total Yes	Grand Total No
LL	EAST	1991			13										13	
		1992					4		3		8				15	
		1993			4		4		18				5		31	
		1994			9										9	
		1995					5		8		6		2		21	
		1996									6				6	
		1997			16										16	
		1998									27				27	
		1999	46		38						27				111	
		2000	28		48						38		21		135	
		2001	2				26		38		10		16		92	
		2002	38		22		43		55		9		19		186	
	LA	1998									242				242	
		1999	40		36										76	
		2000			147						103		66		316	
		2001	108		24								23		155	
		2002	40		102		131		23						296	
	TX	1993			9				22						31	
		1998									116				116	
		2001			36										36	
		2002			24		40								64	
HL	EAST	1991			88		54		48						190	
		1992	109				19		4		6				138	
		1993	11		2		65		28		21		35		162	
		1994	13		37		36		27		50		36		199	
		1995	29		99		28								156	
		1996			2		4		3						9	
		1997			33										33	
		1998									239	489			239	489
		1999	362	311	199	526					109	636	100	134	770	1,607
		2000	357	322	238	515	107	168	2		208	261	104	516	1,016	1,782
		2001	102	574	320	474	475	285	113	9	99	294	100	495	1,209	2,131
		2002	104	380	294	614	432	881	100	390	100	296	192	307	1,222	2,868
	LA	1991					25								25	
		1992	189		25										214	
		1993	85	89	110	443	100	111			1				296	643
		1994	130	285	373	139									503	424
		1995			48										48	
		1998									959	1,638			959	1,638
		1999	341	852	498	979					278	1,047	99		1,216	2,878
		2000	364	324	398	390	101	75			100	223	150	301	1,113	1,313
		2001	108	280	442	487	100	182	63		204	442	100	523	1,017	1,914
		2002	254	545	452	318	327	358	103	170	126	121	135	292	1,397	1,804
	TX	1993	28		31										59	
		1998									140	239			140	239
		1999	336		381						99		29		845	
		2000	46		12										58	
		2001			32		23				61				116	
		2002	98		251		71				24				444	
		TOTAL	3,368	3,962	4,893	4,885	2,220	2,060	658	569	3,416	5,686	1,232	2,568	15,787	19,730

FIN approach:

The Fisheries Information Network (FIN); a state-federal cooperative program which is chiefly coordinated and administered via the Gulf States Marine Fisheries Commission (GSMFC), developed a plan for prioritizing species and setting commercial and recreational targets for age information (GSMFC, 2003).

“These targets were developed based on historical commercial and recreational landings from 1999 and 2000. The numbers of otoliths were determined by multiplying 0.5% by the total number of fish for each state” (GSMFC, 2003).

“It needs to be noted that this is an initial step and the number of samples may be adjusted as more information is collected and becomes available” (GSMFC, 2003).

The year 2002 was the first year for this approach and red snapper was one of four species chosen due to funding levels. The 0.5% sampling fraction was based on an earlier sampling design for king mackerel but was recognized as being somewhat arbitrary as the full rationale was not available (first author’s notes from a December 2000 meeting). It should be noted that more than four species continued to be sampled by state and federal samplers, as there is a list of 29 primary and 40 secondary species of concern, but this occurred on a continuing or ad-hoc basis. The point of the 0.5% fraction was to sample in a representational manner and simply to have a protocol with which to begin the program. With 6 bimonthly sampling periods (waves), 5 states, and 5 modes (3 recreational and 2 commercial), the result was 13,500 targeted red snapper otoliths from over 100 strata each year (GSMFC, 2003). Combining results from Table 1 and from Gulf States (Allman et al. 2004a and based on age data provided by David Donaldson, Gulf States Marine Fisheries Commission), the collection target was exceeded in the first year—2002 (about 17,000 total otoliths). To date, 73% of the 2002 target (about 9,900 otoliths) has been aged based on federal and state tallies (Table 1 and Allman et al. 2004a). A comparison of commercial versus recreational targets is pending.

Prior to the 2002 onset of FIN sampling for red snapper age structure, there were considerations of red snapper sampling needs which served as precedents. Schirripa and Goodyear (1998) recommended 7500 otoliths to be collected annually from the commercial sector as a primary approach to simple random sampling. This number was based on extrapolation of a set percentage of 1997 landings reported at the level of the dealer. For a contingency plan, they recommended 7500 lengths to be measured and 50 otoliths per 1 inch interval be sampled resulting in an annual total of 2000 otoliths. Also in 1998, guidance was provided by the Southeast Fishery Science Center to the Beaufort Headboat sampling program and to MRFSS contractors along the same lines as the Schirripa and Goodyear (1998) primary plan—advocating simple random sampling of these sectors in a representative fashion (series of SEFSC emails).

Potential future sampling targets

Two-phase sampling for age using age-length keys, which takes advantage of low-cost length determination, is often preferred in fisheries monitoring. However, this approach doesn't work well when size-at-age is highly variable (Smith 1989). In a sub-tropical system such as the Gulf of Mexico, variable size-at-age seems to be a robust phenomenon. In a length-age plot, a 10-cm size category approaching the asymptote can span about 52 age classes for gulf red snapper (Allman et al. 2004a). This leads to the desire to directly- and randomly sample the total catch for age structure. Since a principal need for stock assessment is to determine the age proportions characterizing the catch, the age data can be viewed as distributed according to a multinomial distribution (Quinn and Deriso 1999).

Thompson (1987) provides a fishery-based example of sample size determination using multinomial proportions. If a biologist needs to collect a sample of fish such that all age class proportions of the sample are within 0.05 of the population proportions, with 95% confidence, Thompson shows that a conservative and sufficient sample size is 510. This value holds irregardless of the number of age classes in the population. In our case, the population Thompson (1987) refers to is not necessarily the biological population but rather the population of the total catch measured via significant strata. Significant strata would be those groupings that are internally homogeneous and between which you would expect to find notable differences in the age structure. Year would be a significant strata because recruitment and mortality can change age structure annually. Gear would be a significant strata because the ages are notably different among some of the gears. These differences appear to arise from the particular gear selectivities and depths fished. This is clearly observed between longline and hook and line gear (Allman et al. 2002, 2004a). Region may be a significant strata because the underlying stock age structure can be different in different areas due to harvest and possibly migration patterns. There is good evidence that those red snapper susceptable to longlining are of very different age structure in the eastern versus western gulf (Mitchell et al. submitted, Allman et al. 2004). So, considering the two gulf regions and the various gears where differences have been detectable (recreational hook and line, commercial hook and line, and commercial longline), about 3*2 strata per year may be a useful approach to gauge sample size (thus about 3000 otoliths per year from the gulf) until- and if further stratification levels become apparent.

For red snapper, the age differences detected among strata seem to be quite consistent over time. For example, the differences between the eastern and western gulf, detectable among red snapper harvested by longline, seems to have persisted at least since the 1980s and perhaps longer (Mitchell et al. submitted). Even annual differences in age structure, detected from hook and line gear, don't seem to be very dramatic (Allman et al. 2004). Therefore, it doesn't appear that there is much of a risk in developing a bias in the catch age structure as long as these strata can be said to be randomly sampled.

Other forms of stratification may be useful for the administrative convenience of directing collection effort (Cochran 1977). Examples of administrative strata or "cells" are bimonthly periods, states, ports, dealers etc. As mentioned earlier, random sampling is a key assumption for estimating multinomial proportions. Random sampling is not easy to achieve in port sampling. Applying these types of cells to insure representative sampling can also help insure random sampling of the significant strata. While useful to guide sampling, we question whether administrative cells should be used to extrapolate and set an overall annual target sample size as has been advocated in earlier sampling plans. In order to minimize costs and balance resources for work on many species of concern, we propose that overall sampling targets be initially set using significant strata rather than administrative cells. The question of 'what is a significant stratum?' has been a point of debate and our hope is that panelists and others reviewing the 2004 stock assessment will examine this in more detail.

Considerations about aging error

While some stock assessment modeling approaches consider the effects of aging error in attempts to statistically "correct" ages (Richards et al. 1992, Beamish and McFarlane 1995), no sampling design to date that we know of, explicitly accounts for aging error although Gröger (2003) addresses sample size needs for testing bias and degree of random precision error among age readers. The use of multinomial proportions, as well as other sampling-for-age-structure approaches, assumes that ages are determined without error. A factor inhibiting progress is that true measures of aging error are extremely difficult to accomplish and this is an area of active investigation (see Campana 2001).

But in considering a sampling design, any clear choice which would reduce aging error should merit attention. For red snapper, it would be important to minimize aging errors even occurring on the order of one year for the abundant young year classes (e.g., 2-8) as these will be the ages most likely to reveal year-class trends upon annual examination of age structure (see Allman et al. 2004a). Errors of one-year can commonly arise when otolith margins are examined by a reader and a determination must be made whether to advance the age or not. This occurs in the spring through early summer months corresponding to the formation of the opaque zone (Allman et al. 2004b). By restricting sampling to the late summer-fall period, opaque zone formation is complete and the age-advance decision, with its inherent error, is minimized (Allman et al. 2004b). But restricting sampling on a seasonal basis could lead to bias because of the departure from representational sampling. For example, portions of the stock could be seasonally migratory between regions and this would be a concern for species such as king and Spanish mackerel (Doug DeVries, personal communication, NMFS, Panama City). However, for red snapper which does not show notable seasonal migrations among geographic regions[1], late summer-fall sampling may offer no risk of sampling bias but rather only result in a reduction in aging error. We pose this issue as another sampling topic for examination.

[1]There is evidence that adult red snapper can exhibit onshore-offshore movements between summer and winter respectively, and that these movements are tracked in the fishery (Moe 1963, Bradley and Bryan 1975). Other known large-scale movements have been related to event phenomena such as hurricanes (Patterson et al. 2001).

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