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Indicators of Fleet Diversity in the New England Groundfish Fishery

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1. Methods

Consideration of measurement of fleet diversity in the New England groundfish fishery took the groundfish PDT draft report (white paper dated September 17, 2010) on fleet diversity and excessive shares as its starting point. The current study resembles the draft PDT report with important differences. Of particular note are that 1) the current study focuses on the presence or absence of "species" whereas the draft PDT report used landings and 2) the current study maintains the "species" construct throughout whereas the draft PDT report did not. That is, in the draft PDT report fleet diversity was measured separately by port group, vessel size, and gear using the Simpson's index. The manner in which the index was applied is equivalent to redefining the number of species each time. For example, the Simpson's index for vessel size (Figure 6 in the draft PDT report) has to be interpreted as being associated with an "ecosystem" having only 5 species. By contrast, the Simpson's index for port groups (Figure 3 in the draft PDT report) is associated with an ecosystem having 25 species. This complicates any direct comparisons of fleet diversity by port group, vessel size, or gear because they are, in effect, not the same ecosystem or fleet. Furthermore, a property of the Simpson's index is that the lower bound is 1/N where N is the total number of species. For example, the Simpson's index for vessel size cannot take on any value less than 0.2 whereas the minimum index value for port groups is 0.04. In comparing across ecosystems with disparate numbers of species it may be more appropriate to examine the distance between the Simpson's index and its minimum value than it is to compare the value of the Simpson's Index itself. Doing so reveals that the vessel size index is closer to its minimum value in all years than the port group index even though the value of the port group index is well below that of the vessel size index.

In this study fleet diversity is measured by the Shannon index (Shannon, 1948) calculated as

$$SH = -\sum_{i=1}^{N} p_i * ln_e p_i \; where \; p_i = \frac{q_i}{V}$$

where i denotes vessel type, N is the total number of vessel types, p_i is the number of vessels of type i (q_i) divided by total vessels (V). Like the Simpson's index the Shannon index is a weighted average of the proportional abundance of each vessel type in the fleet. The difference between the two lies in the weights applied to the p_i. The Simpson's index is calculated as

$$SI = \sum_{i=1}^{N} p_i^2$$

By squaring the proportional abundance of each vessel type the Simpson's index weights the proportions of "abundant" vessel types more heavily than less abundant or rare vessel types whereas the Shannon index weights all vessel types according to their actual proportions. The treatment of the weights is an important characteristic when converting diversity indices based on proportional abundance into their number equivalents or what is referred to as "true" diversity.

True diversity is the number of vessel types of equal abundance that would be associated with the calculated diversity index. In the biodiversity literature this is referred to as the number of "effective" species. A general formula for effective species based on Hill (1973) is given by

$$^{q}D \equiv \left(\sum_{i=1}^{N} p_i^q\right)^{1/(1-q)}$$

where q is referred to as the diversity order. The order of diversity is related to its sensitivity to common and rare vessel types (Jost, 2006). Diversity of order 0 is insensitive to proportional abundance and is equal to the number of vessel types (species richness). In this case, the fact that there are more of some vessel types than others is completely irrelevant. Diversity orders less than 1 would give more weight to rare vessel types while diversity orders greater than 1 give more weight to common vessel types. Only the Shannon index (diversity of order 1) weighs all frequencies for rare and common vessel types equally. True diversity for the Shannon index is calculated as

$$^{1}D = e^{SH}$$

True diversity for the Simpson's index is equal to its inverse. Except in the case where frequencies of all vessel types are exactly the same, true diversity using the Simpson's index will be less than that measured by the Shannon index.

The construction of the Shannon index means that the index for groups of vessel types are additive across all groups. This is also true of the Simpsons index. In this manner the contribution of sub-groups to the diversity index can be identified to examine trends in specific components of the fleet. These trends can be examined based on the absolute value of the partial index or each sub-group's share in the total index.

2. Data

Vessel type or "species" was based on gear, vessel size, port-group, and area fished (inshore/offshore). The draft PDT report did not include area fished because at the time the report was drafted the guidance to the PDT was limited to gear, size, and regional considerations. The draft PDT report included both limited access and open access groundfish permits. In this study separate analyses were conducted for all active groundfish permits (open and limited access), all active groundfish permits that landed at least one pound of groundfish, all active limited access permits, and all active limited access permits that landed at least one pound of groundfish. Throughout, active was defined as having landed at least one pound of any species and groundfish species was defined as any of the 10 "large mesh" species regulated under the Northeast Multispecies FMP. The permit application data base was used to determine valid groundfish permits by fishing year from 1994 – 2011 and whether the permit was open or limited access. Note that Handgear A (HA) permits which did not exist prior to 2004 were not included in the analyses conducted for limited access permits to provide for a consistent treatment of limited access permits over the entire time series. Inclusion of the HA permits would have resulted in a change in the diversity index from 2004 onward that would reflect a change in permit status and not a change in the underlying fleet diversity. Note that HA permits were considered in the analyses that included all groundfish permits.

Vessel size categories were identical to that used in the draft PDT report. These sizes were less than 30 feet, 30 to less than 50 feet, 50 feet to less than 75 feet, and 75 feet or greater. The permit application data were used to determine vessel length. Note that "unknown" vessel size was not included in this study whereas the draft PDT report included unknown vessel size which was necessary since the draft PDT report included a time period over which under-tonnage vessels were excluded from the dealer data.

Gear categories were similar to that used in the draft PDT report except that gears other than bottom longline, hook and line, gillnet, and trawl were treated as a single "other" gear. A single gear category was assigned to each active groundfish permit holder based on whether any groundfish were landed. These determinations were made using Vessel Trip Report (VTR) data for two reasons. First, as noted in the draft PDT report the volume of missing data for gear in the dealer data has increased due to conversion to dealer electronic reporting beginning in 2004. Second, dealer data in Connecticut and Delaware do not identify unique vessels. This means that reliance on dealer data for operators that land most of the time in either of these two states would compromise the ability to classify these vessels based on gear, port-region or area fished. For vessels that landed any groundfish the gear category was based on whichever gear accounted for the majority of total pounds of all species landed on groundfish trips. Gear categories for vessels that did not land any groundfish were determined by whichever gear accounted for the majority of total landings.

Port groups in the draft PDT report were based on the port groups as they had been defined in Amendment 13. The port-regions in the present study were based on somewhat larger aggregations of counties for two reasons. First, the aggregations chosen match those of the Northeast Region Input-Output model (see Table 1) and are similar to the regions identified in Amendment 13. Second, the larger aggregations allow for some movement among ports within a region without classifying that movement as a change in diversity. Diversity indices need to be understood as aggregate indicators and while it is tempting to add species it may also make it harder to detect changes in diversity. Assignment of each vessel to a region began with assigning every trip to a region based on state and county of landings as reported in the VTR. For vessels that landed groundfish, the assigned region was determined by the region in which the majority of landings were reported for of all species on trips that landed groundfish. For vessels that did not land any groundfish the region was determined by whichever region the majority of total landings were reported.

Inshore/Offshore designation was based on whether the majority of all reported landings of any species were harvested in inshore or offshore statistical areas as reported in the VTR. For purposes of this study, inshore statistical areas were defined as any statistical area that was adjacent to the shoreline of any state. All other statistical areas were defined as offshore (see Table 2).

Table 1. Northeast Region Input/Output Model Regions	
Region Name	County
Downeast, ME	Washington
Upper Mid-Coast, ME	Hancock, Knox, Waldo
Lower Mid-Coast, ME	Androscoggin, Cumberland, Kennebec, Lincoln, Sagadahoc
Southern, ME	York
NH Seacoast	Hillsborough, Rockingham, Strafford
Gloucester, North Shore	Essex
Boston Area	Middlesex, Norfolk, Plymouth, Suffolk
Cape and Islands	Barnstable, Dukes, Nantucket
New Bedford, South Shore	Bristol
Rhode Island	Bristol, Kent, Newport, Providence, Washington
CT Sea Coast	Fairfield, Middlesex, New Haven, New London
NY Coastal	Bronx, Kings, Nassau, New York, Queens, Richmond, Rockland, Suffolk, Westchester
NJ North	Bergen, Essex, Hudson, Morris, Passaic, Sussex, Union, Warren
NJ South	Atlantic, Burlington, Camden, Cape May, Cumberland, Gloucester, Hunterdon, Mercer, Middlesex, Monmouth, Ocean, Salem, Somerset
DE Coastal	Kent, New Castle, Sussex
MD West	Anne Arundel, Baltimore, Baltimore City, Carroll, Cecil, Harford, Howard, Montgomery, Prince George
MD East	Calvert, Caroline, Charles, Dorchester, Kent, Queen Anne's, St. Mary's, Somerset, Talbot, Wicomico, Worcester
VA East	Accomack, Northampton
VA North	Essex, Fairfax, King and Queen, King George, King William, Lancaster, Manassas City, Manassas Park City, Middlesex, New Kent, Northumberland, Prince William, Richmond, Stafford, Westmoreland
VA South	Charles City, Chesapeake City, Chesterfield, Colonial Heights City, Gloucester, Hampton City, Henrico, Isle of Wight, James City, Mathews, Newport News City, Norfolk City, Poquoson City, Portsmouth City, Prince George, Richmond City, Suffolk City, Surry, Virginia Beach City, Williamsburg City, York
NC North	Bertie, Camden, Chowan, Currituck, Pasquotank, Perquimans, Tyrell Washington
NC Central	Beaufort, Carteret, Craven, Dare, Hyde, Pamlico, Pitt
NC South	Brunswick, New Hanover, Onslow, Pender

Table 2. List of Inshore and Offshore Statistical Areas

Inshore Statistical Areas	511, 512, 513, 514, 521, 537, 538, 539, 611, 612, 613, 615, 614, 621, 625, 631, 635
Offshore Statistical Areas	515, 522, 523, 561, 562, 525, 526, 542, 543, 541, 533, 534, 616, 622, 623,624, 626, 627, 628, 629, 632, 633, 634, 636, 637, 638, 639

3. Results

The four characteristics (5 gear types, 4 vessel sizes, 23 regions, and inshore/offshore) used to distinguish one vessel type from another results in a potential of 920 unique vessel types. Of course, the actual number of vessel types in any given fishing year was much lower and differed depending on whether the analysis included all or just limited access groundfish permits and whether the analysis was limited to permits that landed any species or permits that landed some groundfish. As will be seen, the estimated effective diversity based on the Shannon index was substantially less than the total number of vessel types (richness) for all analyses. This occurs for two reasons one of which has to do with the mathematical property of the index while the other has to do with the methods used to designate vessel types.

Although true Shannon diversity (the numbers equivalent of the index) does not disproportionately treat rare or common vessel types, the index itself is based on proportions. Mathematically, this means that the effect on the index of losing the most common vessel type will be larger than the effect of losing the least common vessel type. Note that under these conditions the effect on the Simpson's index would be even larger since the Simpson's index weights common species more heavily than rare species. To illustrate, for all groundfish permits there were a total of 228 different vessel types that were active during fishing year 1994. Of these vessel types the one with the highest frequency accounted for 3.72% of total vessels. By contrast, there were 69 vessel types each having only one vessel of each type. Each of these "rare" vessel types accounted for 0.06% of the total fleet. The Shannon effective diversity for this fleet composition for 1994 was 114. Losing just the most common vessel type would result in a 13% reduction in effective diversity, but would only result in a 0.4% reduction in richness. By contrast, losing up to 29 of the least common vessel types would have the same 13% impact on Shannon effective diversity as that of losing the one most common vessel type, but would also result in a 13% reduction in richness.

The asymmetric treatment of rare "species" as compared to abundant species is of some consternation in the biodiversity literature as the loss of rare species may have important implications for ecosystem function. The implication of losing vessel types with low numbers on fleet diversity is less obvious. Fishing vessels are fungible assets that may enter and exit a fishery depending on economic conditions or may change gears, fishing location, or base of operation. Furthermore, the manner in which vessel type designations had to be made forces a razor's edge determination that is likely to be more rigid than how the groundfish fleet actually operates. Many vessels fish with more than one gear, and land groundfish in multiple ports. Forcing each vessel into a single category is likely to result in classifications that may be suitable for the most common types of vessels, but may increase the likelihood that unusual or infrequent vessel types will be identified. For this reason, the Shannon effective diversity measure may be a more reliable indicator of fleet diversity than richness since it will be less sensitive to rare or unusual vessel types resulting from measurement error. That said, the Shannon diversity measure will retain the ability to detect changes in richness and may be better suited to detect changes in relative abundance of the more common vessel types.

3.1 All Active Groundfish Permits

The number of open access and limited access vessels that landed any species on at least one trip ranged was 1,800 vessels during 1994 (Table 3). There were approximately 2,000 or more active groundfish permitted vessels in every year from 1995 to 2002. Thereafter, the number of active vessels declined at an average annual rate of 95 vessels per year to 1,237 vessels in fishing year 2011. In general species richness and both the Shannon and Simpson's effective diversity exhibit similar trends. Compared to 1994 the 2011 both the Shannon and Simpson's effective diversity had declined by 17% while richness had declined by 16%. As noted previously, Shannon effective diversity was lower than richness and the Simpson's effective diversity was lower still. Nevertheless, each diversity measure shares several common features. All the indicators show declines from 1994 to 1997 followed by relative stability from 1998 to 2001 and then a drop in diversity in 2002 (Figure 1).

Table 3. Fleet Diversity Indicators for all Active Groundfish Permits

Fishing Year	Fleet Size	Richness	Shannon Index	Shannon Effective Diversity	Simpson's Index	Simpson's Effective Diversity
1994	1,800	228	4.743	115	0.013	75
1995	2,028	238	4.721	112	0.014	72
1996	1,982	220	4.665	106	0.015	68
1997	2,018	213	4.633	103	0.015	66
1998	2,019	232	4.662	106	0.015	66
1999	2,117	233	4.657	105	0.015	65
2000	2,178	234	4.654	105	0.015	66
2001	2,172	237	4.656	105	0.016	64
2002	2,069	233	4.625	102	0.016	61
2003	1,874	217	4.627	102	0.015	66
2004	1,812	220	4.637	103	0.015	67
2005	1,698	211	4.607	100	0.015	67
2006	1,645	205	4.595	99	0.015	66
2007	1,568	204	4.628	102	0.014	69
2008	1,459	193	4.599	99	0.015	67
2009	1,400	189	4.540	94	0.016	61
2010	1,365	198	4.568	96	0.017	60
2011	1,237	190	4.549	95	0.016	62

Beginning in 2002, however, richness exhibited a steeper decline in diversity as compared to either the Shannon or Simpson's effective diversity. Specifically, richness declined by an average annual rate of 2.2% from 2002 to 2011 while Shannon effective diversity declined by less than 1%. Simpson's effective diversity stayed relative constant and even increased in 2007 before declining in 2009 and 2010. The difference in trends displayed between richness and effective diversity is a reflection of fleet contraction in less abundant vessel types where richness displays greater sensitivity to the mere presence or absence of vessel types.

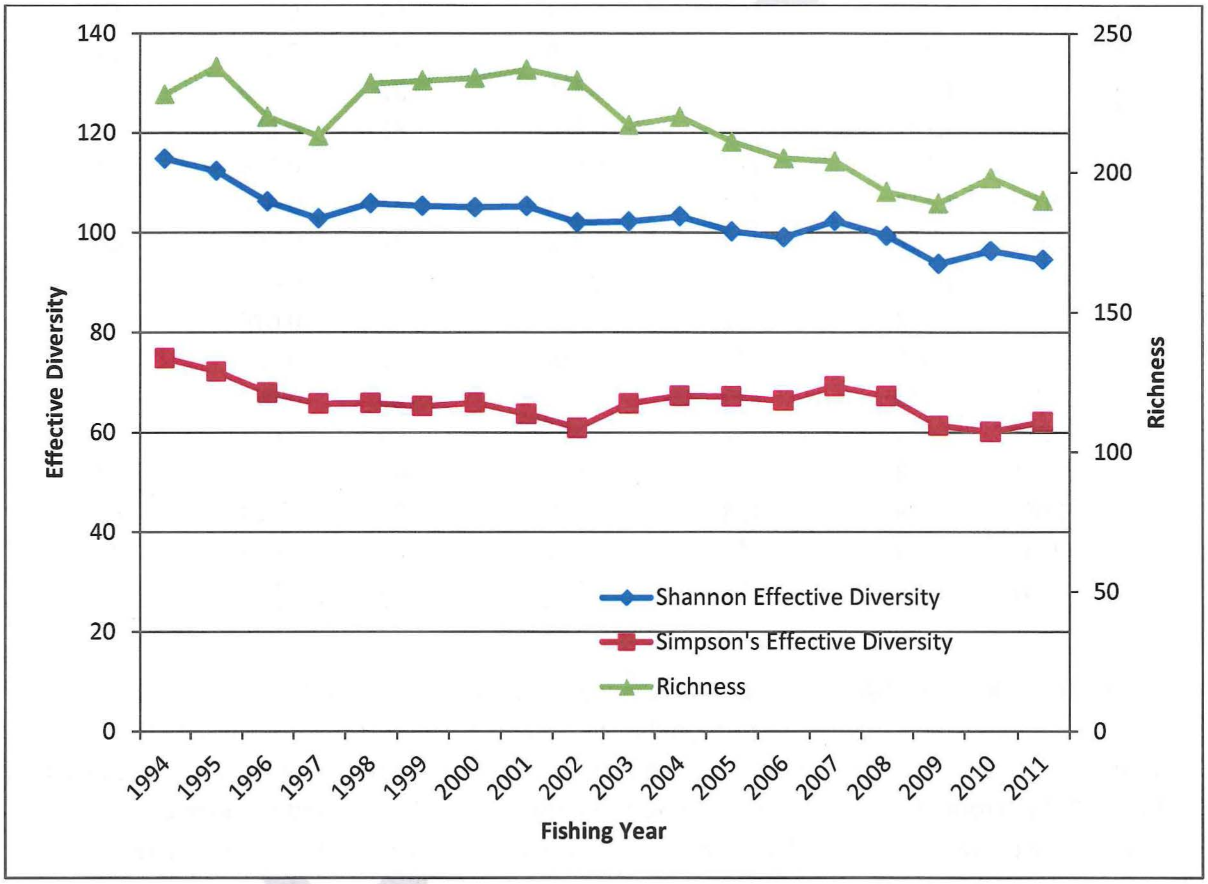

Figure 1. Richness and Shannon and Simpson's Effective Diversity (Fishing Year 1994-2011)

3.2 All Active Groundfish Permits with Groundfish Landings

The total number of open and limited access permit holders that also landed one or more pounds of regulated mesh groundfish was 1,373 in fishing year 1994 (Table 4). The number of groundfish permit holders that landed groundfish increased in both 1995 and 1996, but began trending downward through 2001 at gradual average annual rate of 1.1%. However, after 2001 the downward trend in open and limited access vessel participating in the groundfish fishery accelerated through 2010 declining by an average of 83 vessels per year. In 2010 and 2011 was nearly identical at 494 and 492 vessel respectively.

Table 4. Fleet Diversity Indicators for all Active Groundfish Permits with Groundfish Landings

Fishing Year	Fleet Size	Richness	Shannon Index	Shannon Effective Diversity	Simpson's Index	Simpson's Effective Diversity
1994	1,373	197	4.538	93	0.017	60
1995	1,447	202	4.564	96	0.016	61
1996	1,396	182	4.485	89	0.018	57
1997	1,331	169	4.428	84	0.018	54
1998	1,299	171	4.439	85	0.019	54
1999	1,277	173	4.449	86	0.018	56
2000	1,298	180	4.446	85	0.019	54
2001	1,320	168	4.404	82	0.020	49
2002	1,216	164	4.363	78	0.022	46
2003	1,089	152	4.335	76	0.020	49
2004	944	141	4.320	75	0.020	51
2005	845	135	4.288	73	0.020	50
2006	743	125	4.222	68	0.021	48
2007	698	122	4.239	69	0.021	48
2008	663	115	4.162	64	0.023	44
2009	599	118	4.150	63	0.024	41
2010	494	111	4.171	65	0.023	44
2011	492	117	4.227	69	0.021	48

Like fleet size, indicators of diversity (richness, Shannon effective diversity and Simpson's effective diversity) have exhibited a downward trend, although richness has declined at a faster rate than either measure of effective diversity since 2002 (Figure 2). More recently effective diversity increased in both 2010 and 2011. From 1995 through 2002 richness (number of vessel types) and Shannon effective diversity followed identical trends declining at an average annual rate of 2.8%. Simpson's effective diversity also declined albeit at a higher rate of 3.8%. Since 2002, richness has declined at an average annual rate of 4.5% whereas Shannon effective diversity and Simpson's effective diversity declined more slowly averaging 2.9% and 1.7% respectively at least through 2009. In 2010 and 2011 both the Shannon and Simpson's effective diversity increased. Effective diversity declined at a lower rate than richness since 2002 because the relative abundance by vessel type has become more even over time. To illustrate, the Gini coefficient may be used to measure the deviation of the actual distribution of frequencies by vessel type to one of a uniform distribution (reference). The Gini coefficient for fishing years 1994 to 2002 was nearly constant ranging from a low of 0.630 in 1998 to a high of 0.644 in 1994. Since 2002, the Gini coefficient has been steadily declining reaching a low of 0.565 in 2011. This trend means that differences in relative abundance between more common and less common vessel types have been reduced which accounts for the lower rate of decline in effective diversity as compared to richness. The Gini coefficient was lowest in 2011 which means that there was less difference in relative frequencies among more common and less common vessel types in 2011 than there was in prior years.

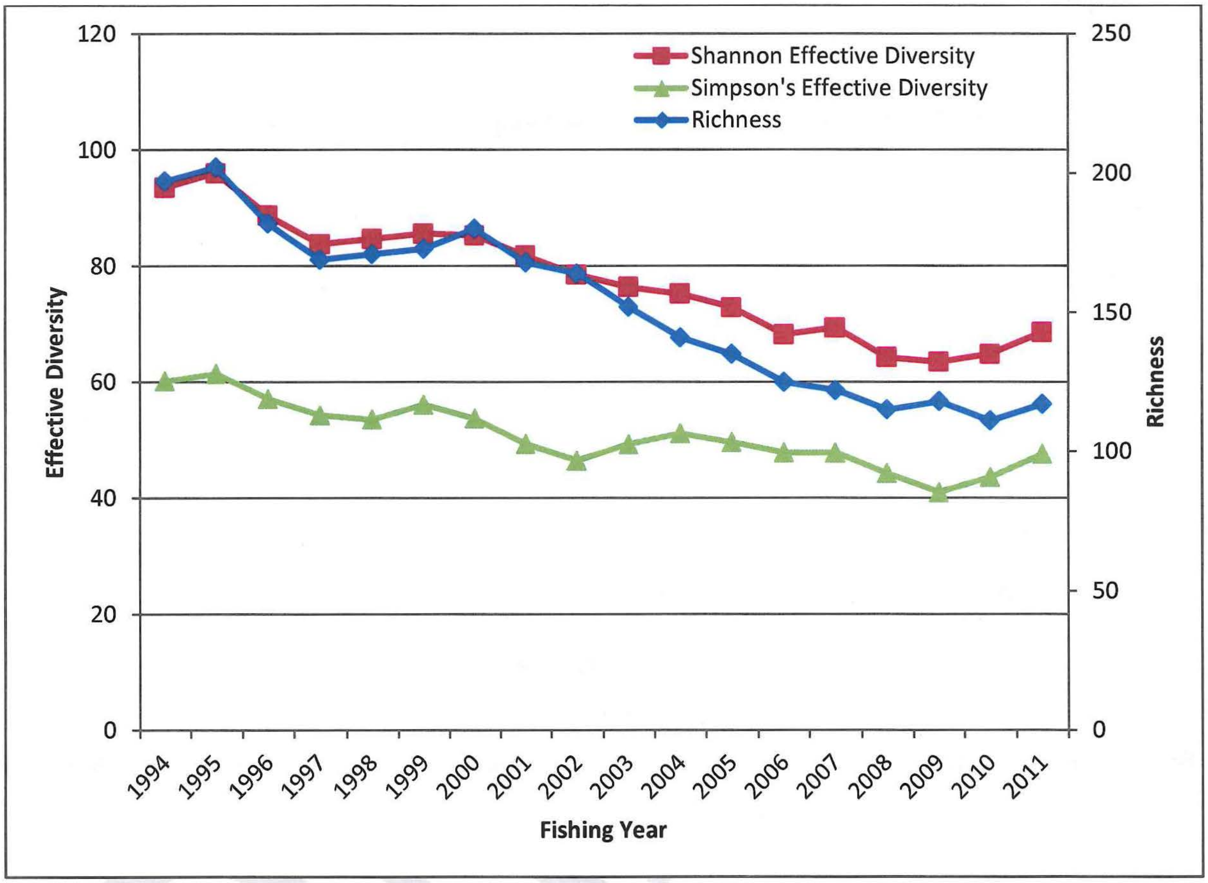

Figure 2. Effective Diversity and Richness for Any Groundfish Permit with Landings of Groundfish

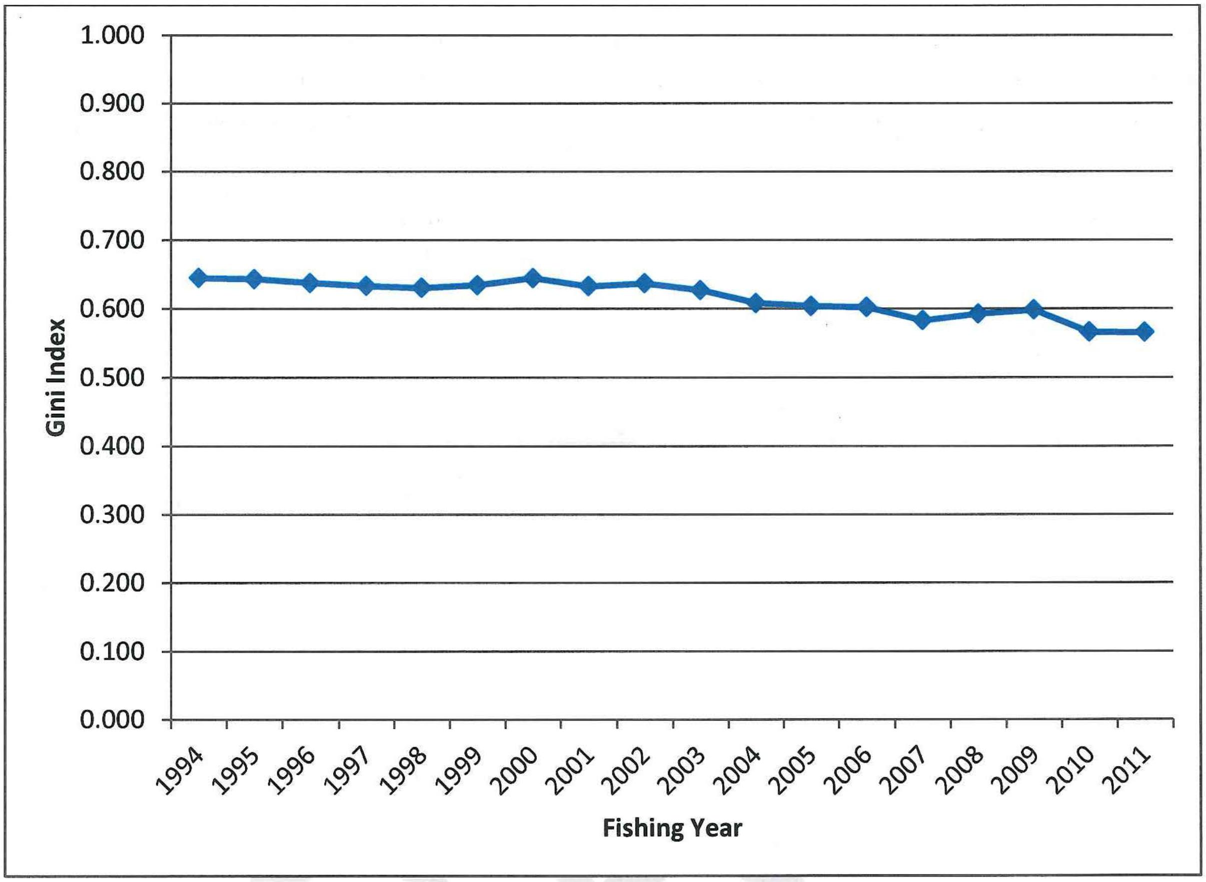

Figure 3. Gini Index for Frequency Distribution of Vessel Types for Groundfish Permits with Landings of Groundfish

3.3 All Active Limited Access Groundfish Permits

The number of vessels holding any kind of limited access permits was 1,395 in 1994 and was highest in 1996 (Table 5). There were at least 1,400 active limited access vessels in every year from 1995 through 2001. Over these years the size of the active limited access fleet had been declining at an average rate of 19 vessels per year from the high of 1,498 vessels in 1996 to 1,405 vessels in 2001. Beginning in 2002 (the year in which DAS were redefined via the Settlement Agreement) attrition in the active limited access groundfish fleet accelerated dropping by 186 vessels from 2001 to 2002 and declining by an average annual rate of 58 vessels per year from 2003-2011.

Table 5. Fleet Diversity Indicators for all Active Limited Access Groundfish Permits

Fishing Year	Fleet Size	Richness	Shannon Index	Shannon Effective Diversity	Simpson's Index	Simpson's Effective Diversity
1994	1,395	194	4.608	100	0.015	67
1995	1,426	193	4.586	98	0.015	66
1996	1,498	189	4.573	97	0.015	65
1997	1,475	188	4.581	98	0.015	66
1998	1,421	197	4.599	99	0.015	66
1999	1,413	189	4.549	95	0.016	64
2000	1,407	191	4.556	95	0.016	63
2001	1,405	198	4.597	99	0.015	65
2002	1,219	185	4.569	96	0.016	64
2003	1,175	173	4.524	92	0.016	62
2004	1,111	163	4.489	89	0.016	62
2005	1,015	155	4.444	85	0.017	60
2006	974	148	4.425	83	0.017	61
2007	910	152	4.466	87	0.016	61
2008	836	141	4.414	83	0.017	58
2009	799	142	4.415	83	0.018	56
2010	753	145	4.450	86	0.017	59
2011	693	140	4.417	83	0.017	59

Although total fleet size contracted by at least 50% from 1994 to 2011, the number of vessel types declined by 28% while Shannon effective diversity declined by 17% and Simpson's effective diversity declined by only 12%. As noted previously these differences in the diversity indicators are due to the fact that richness does not distinguish between rare or unusual vessel types whereas both the Shannon's and Simpson's effective diversity do. In this context, the Simpson's index may be thought of as an indicator of effective diversity among the most common or perhaps "core" limited access vessel types whereas the Shannon effective diversity reflects changes in common and less common vessel types.

The trends among diversity indicators show that both richness and Shannon's effective diversity track one another from 1994 to 2001, but the rate of change in richness exceeded that of the Shannon effective diversity in every year thereafter (Figure 4). Notably, Simpson's effective diversity has been declining, but at a substantially lower annual rate than either richness or Shannon's effective diversity. This is an indication that the relative proportions of the most common active limited access vessel types has not changed all that much since 1994 even as the relative frequency of less common vessel types has been declining.

From 1994 to 2001 richness increased in some years and declined in others. In fact, over these years the average annual change in richness was slightly positive at 0.33% whereas the average annual change in Shannon's effective diversity was negative -0.12%. However, since 2001 richness has declined at an annual average rate (3.34%) that was nearly twice that of Shannon's effective diversity (1.74%). As noted previously, the divergence between richness and Shannon's effective diversity is due differences in the sensitivity of the two measures to changes in relative abundance of common and less common vessel types and to the fact that the differences relative abundance has been declining as measured by the Gini Coefficient which has been declining over time (Figure 5).

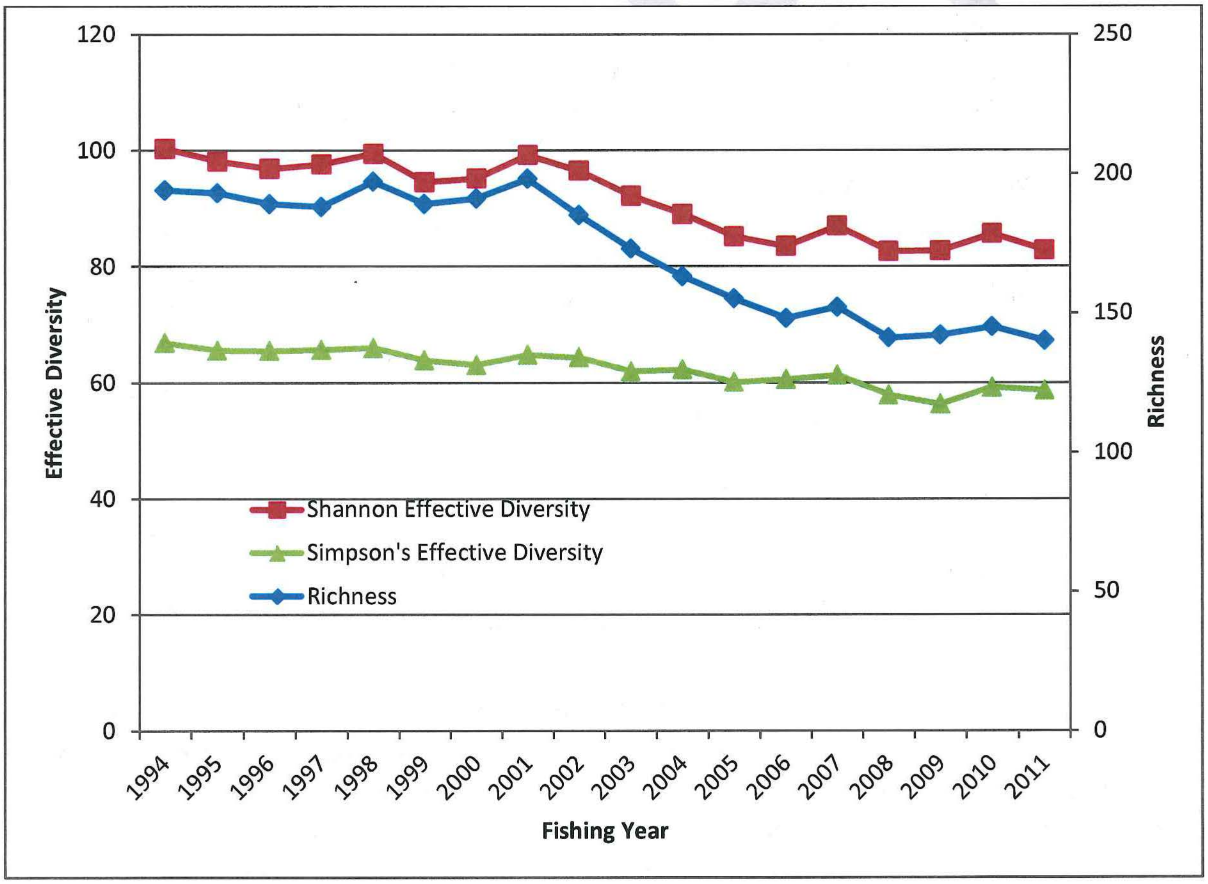

Figure 4. Effective Diversity and Richness for Active Limited Access Vessels

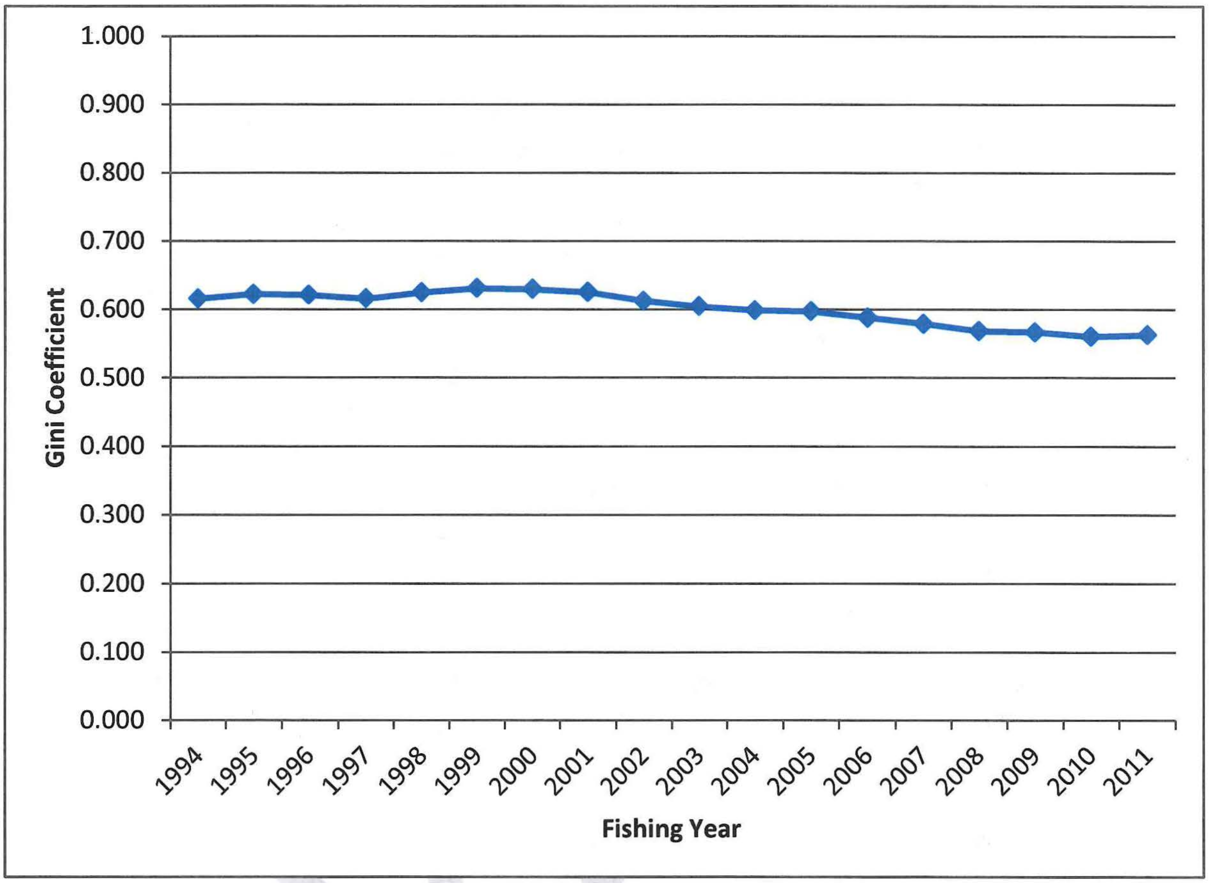

Figure 5. Gini Coefficient for Active Limited Access Vessels

3.4 All Active Limited Access Groundfish Permits with Groundfish Landings

The number of limited access groundfish vessels that landed groundfish on at least one trip was at least 1,000 vessels in every year from 1994 to 2001, but has since declined to 372 vessels in 2011 (Table 6). Compared to 1994, the 2011 fleet size declined by 68% and the indicators of fleet diversity richness, Shannon's effective diversity, and Simpson's effective diversity have declined by 49%, 39%, and 38% respectively. As previously noted each of these measures show distinct changes in trend from 1994-2001 (pre-Settlement Agreement) and from 2002-2011 (post-Settlement Agreement). Specifically, fleet size was contracting at an average annual rate of 1% (12 vessels per year) from 1994-2001. From 2002 to 2011 fleet size declined by an average annual rate of nearly 10% or about 78 vessels per year. Similarly, the number of vessel types and effective diversity declined by approximately 1% per year from 1994-2001, but declined at a much faster average annual rate from 2002 to 2011.

Table 6. Flee Diversity Indicators for Limited Access Permits with Groundfish Landings

Fishing Year	Fleet Size	Richness	Shannon Index	Shannon Effective Diversity	Simpson's Index	Simpson's Effective Diversity
1994	1153	166	4.425	84	0.018	56
1995	1162	168	4.431	84	0.018	55
1996	1206	176	4.392	81	0.018	55
1997	1146	157	4.349	77	0.019	52
1998	1113	152	4.378	80	0.019	53
1999	1077	155	4.361	78	0.019	53
2000	1060	155	4.329	76	0.020	49
2001	1069	155	4.359	78	0.020	51
2002	949	147	4.294	73	0.021	48
2003	878	132	4.207	67	0.023	44
2004	771	119	4.102	60	0.024	41
2005	719	114	4.075	59	0.025	40
2006	641	99	4.008	55	0.025	39
2007	586	96	3.976	53	0.027	37
2008	538	86	3.905	50	0.029	34
2009	473	91	3.876	48	0.033	30
2010	374	88	3.876	48	0.033	31
2011	372	85	3.927	51	0.029	35

As noted above, all three fleet diversity indicators exhibit similar trends from 1994 to 2001 declining at an average annual rate of 1% or less (Figure 6). Since 2001 fleet diversity has declined more rapidly. However, average annual change in fleet diversity differed substantially from 2002 to 2004 (pre-Amendment 13) and from 2005-2011 (post-Amendment 13). Richness declined by an average annual rate of 8.4% from 2002-2004, but declined by a lower annual rate of 4.5% from 2005-2011. Similarly, Shannon's effective diversity also declined at an average annual rate of 8.2%, but declined at an average annual rate of 2.4% from 2005-2011. This was also the case for Simpson's effective diversity although the average annual change in Simpson's effective diversity was less than that for Shannon's effective diversity. As was the previously the case the annual changes in effective diversity were less than that of richness, because the relative frequencies among more and less common vessel types were becoming more even as evidenced by the higher rate of change in the Gini coefficient from 2005-2011 as compared to 1994-2004.

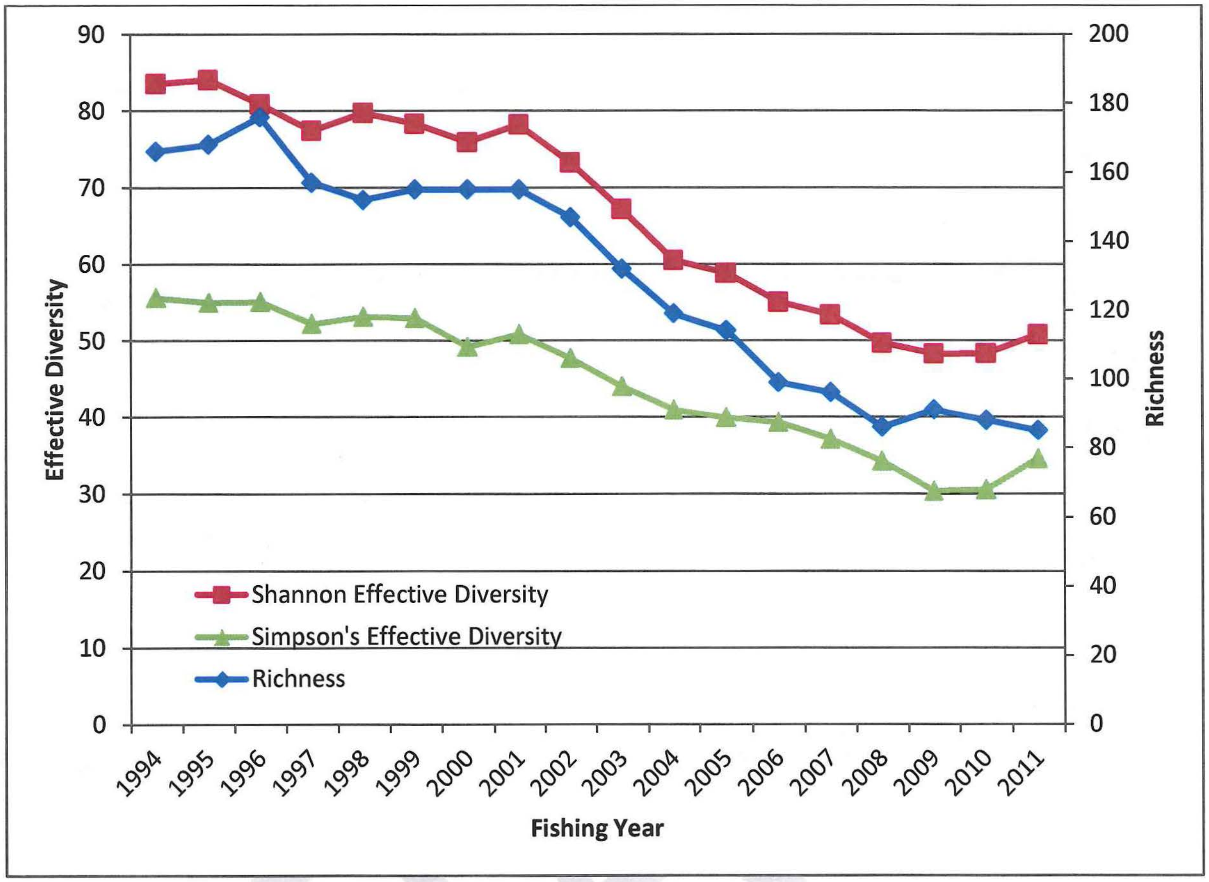

Figure 6. Fleet Diversity Indicators for Limited Access Permits that Landed Groundfish

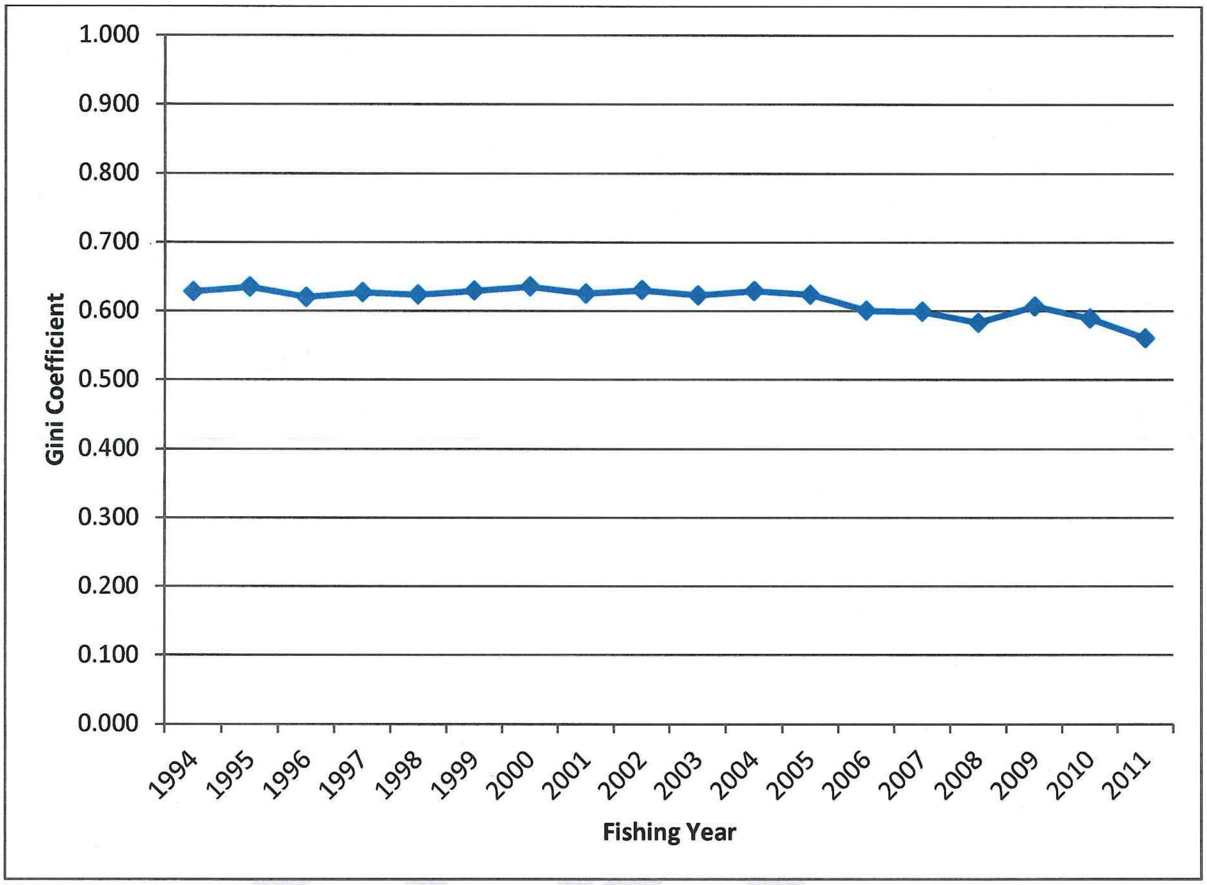

Figure 7. Gini Coefficient for Limited Access Vessels that Landed Groundfish

For the fleet of limited access permits that landed groundfish there were a total of 279 unique vessel types that appeared in at least one year from 1994-2011. Of these, there were 45 vessel types (see Table 7) that appeared in every year while there were 49 vessel types that appeared in only one year and an additional 35 vessel types that appeared in only two years (Figure 8). The former may constitute a "core" component of the fleet as these vessels represented 60 to 70% of the Shannon index, landed pounds of groundfish, and total fleet size from 1994 to 2001 (Figure 9). More recently these core vessel types have accounted for about 80% of both landed groundfish and active limited access permits and has accounted for nearly 77% of the Shannon index.

Table 7. List of Limited Access Vessel Types Landing Groundfish that Were Present in Every Year from 1994 to 2011

Region	Area Fished	Gear	Size Class
Upper Mid-Coast Maine	Inshore	Trawl	30 to < 50, 50 to < 75
Lower Mid-Coast Maine	Inshore	Trawl	30 to < 50, 50 to < 75
		Gillnet	30 to < 50
	Offshore	Gillnet	30 to < 50
Southern Maine	Inshore	Gillnet	30 to < 50
		Trawl	30 to < 50
NH Seacoast	Inshore	Gillnet	30 to < 50
		Trawl	30 to < 50, 50 to < 75
Gloucester, North Shore	Inshore	Gillnet	30 to < 50
		Hook	30 to < 50
		Trawl	30 to < 50, 50 to < 75, 75+
	Offshore	Gillnet	50 to < 75
Boston Area	Inshore	Gillnet	30 to < 50, 50 to < 75
		Hook	30 to < 50
		Trawl	30 to < 50, 50 to < 75, 75+
	Offshore	Trawl	75+
Cape and Islands	Inshore	Gillnet	30 to < 50
		Hook	30 to < 50
		Longline	< 30, 30 to < 50
		Trawl	30 to < 50, 50 to < 75
New Bedford, South Shore	Inshore	Gillnet	30 to < 50
	Offshore	Other	75+
		Trawl	50 to < 75, 75+
Rhode Island	Inshore	Gillnet	30 to < 50
		Other	30 to < 50
		Trawl	30 to < 50, 50 to < 75, 75+
	Offshore	Trawl	75+
Seacoast, NY	Inshore	Gillnet	30 to < 50
		Trawl	30 to < 50, 50 to < 75
Northern NJ	Inshore	Trawl	30 to < 50, 50 to < 75

In addition to the vessels that were always present or vessel types that were rarely so, there were a number of vessel types that appeared in multiple years some of which appeared in multiple consecutive years while others appeared sporadically. These sporadic vessel types as well as the rare vessel types may be the result of the decision rules used to define vessel types and not necessarily to a real change in diversity. Note that while the contraction of the fleet as a whole is unambiguous, it is the uncertainty created by the razor's edge classification for each vessel that complicates interpretation of the loss and appearance of vessel types as a real change in fleet diversity. For this reason the following examines whether there have been any notable systematic trends in diversity by gear, vessel size, state, or area fished.

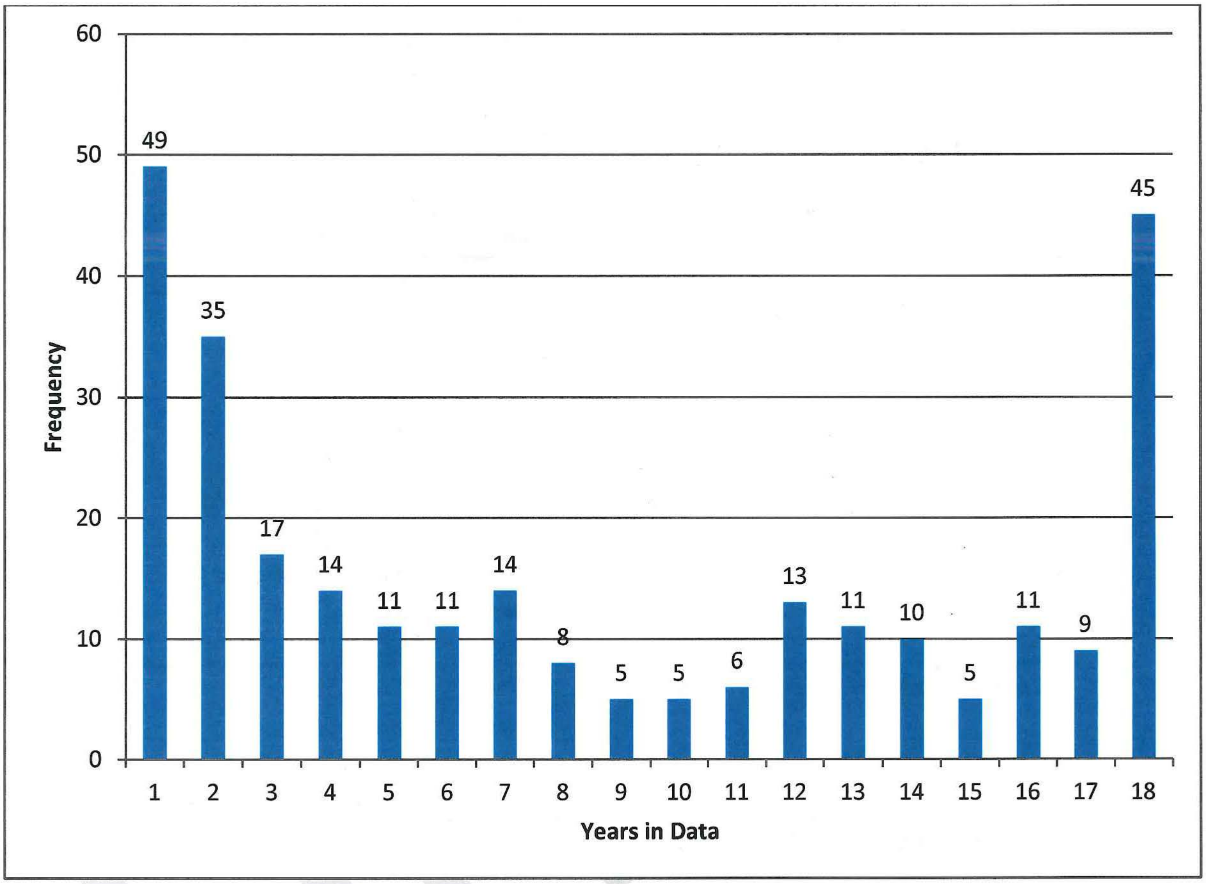

Figure 8. Frequency Counts of Vessel Types by Number of Years Present in the Limited Access Groundfish Fishery

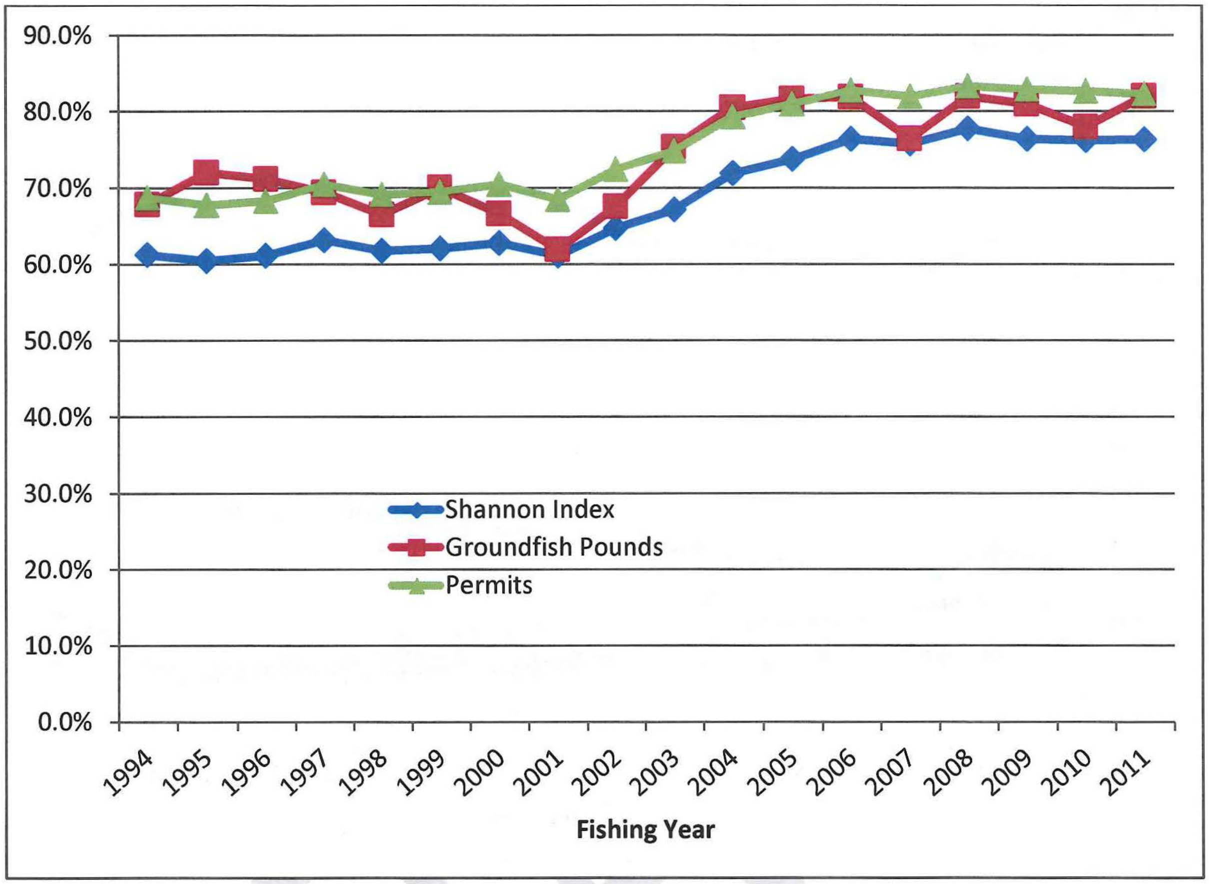

Figure 9. Proportion of Shannon Index, Landed Groundfish Pounds, and Total Fleet Size for Limited Access Vessel Types that Appeared in 18 Consecutive Years from 1994-2011

The Shannon index is additive such that the relative role of sub-components of specific vessel types of interest can be examined. Trawl gear has represented more than half of the Shannon diversity index ranging from a low of 51% in fishing year 1996 to a high of 62% of the index in 2007 (Figure 10). Trawl gear plays a dominant role in the diversity index because there are a comparatively large number of trawl gear vessel types with high relative abundance for some of these vessel types. Gillnet gear averaged 18% of the diversity index from 1994 to 2001, but has been on an increasing trend accounting for 25% of the index in 2011. By contrast, relative role of trawl gear has been decreasing since 2007 at an average rate of 3.6%. On average, longline gear accounted for about 12% of the diversity index from 1996 to 2003, but has since declined to just over 4% in 2011. Similarly, rod & reel gear average 6.6% of the Shannon index from 1996 to 2006, but has also declined in recent years to between 4 and 5.4%.

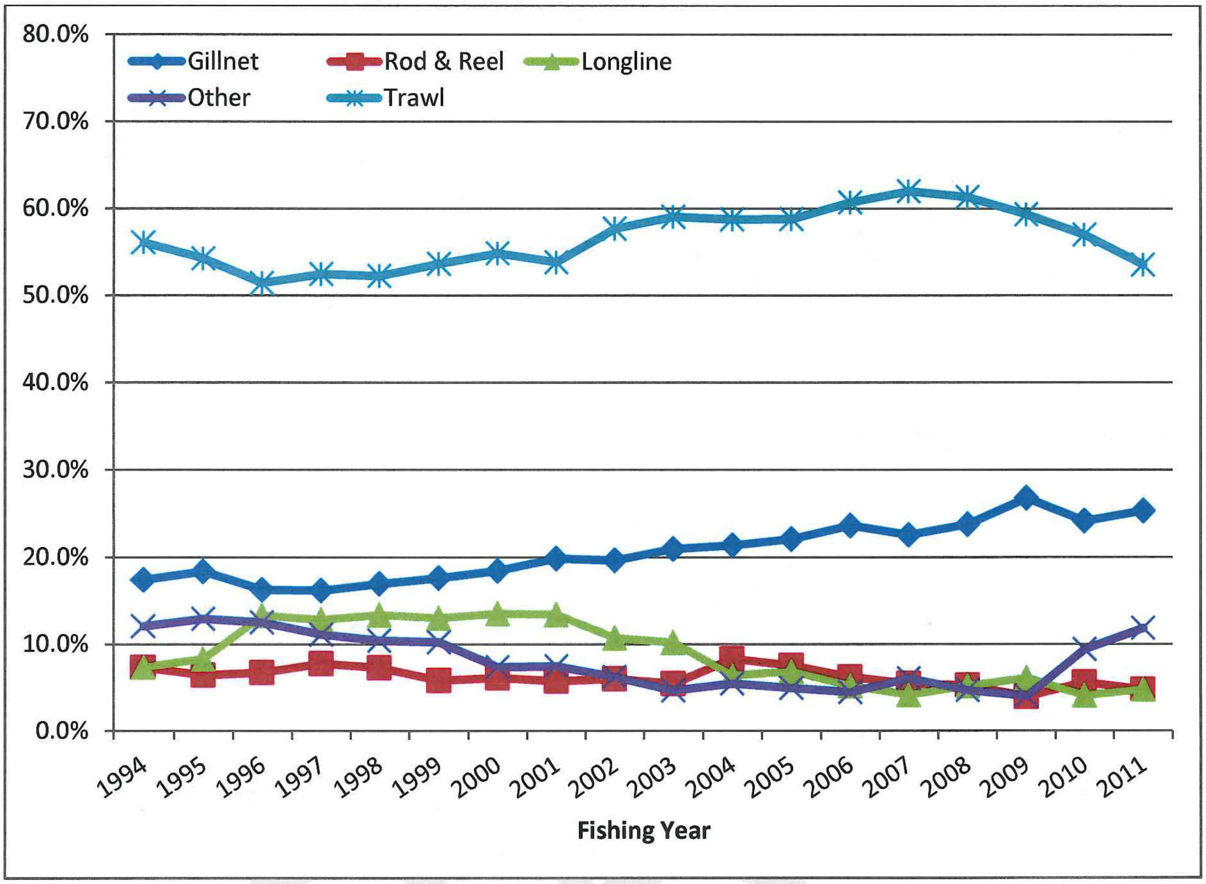

Figure 10. Share of Shannon Diversity Index by Gear for Limited Access Vessel Types that Landed Groundfish

Small vessel less than 30 feet accounted for 6.5% of the Shannon diversity index from 1996 to 2001 (Figure 11). The contribution of these small vessel has since declined to at an annual average rate of 12% from 2002-2006, but has since stabilized at around 2.5% from 2007-2011. Vessels ranging from 30 feet to less than 50 have accounted for the majority of the Shannon diversity index ranging from a high of 50.4% in 2001 to a low of 46.7% in 2011. Note that the 2011 share was not unusually low since vessels in this size class had accounted for approximately 47% of the index on 5 other occasions. However, the relative role of vessels from 30 to 50 feet has been on a downward trend since 2008.

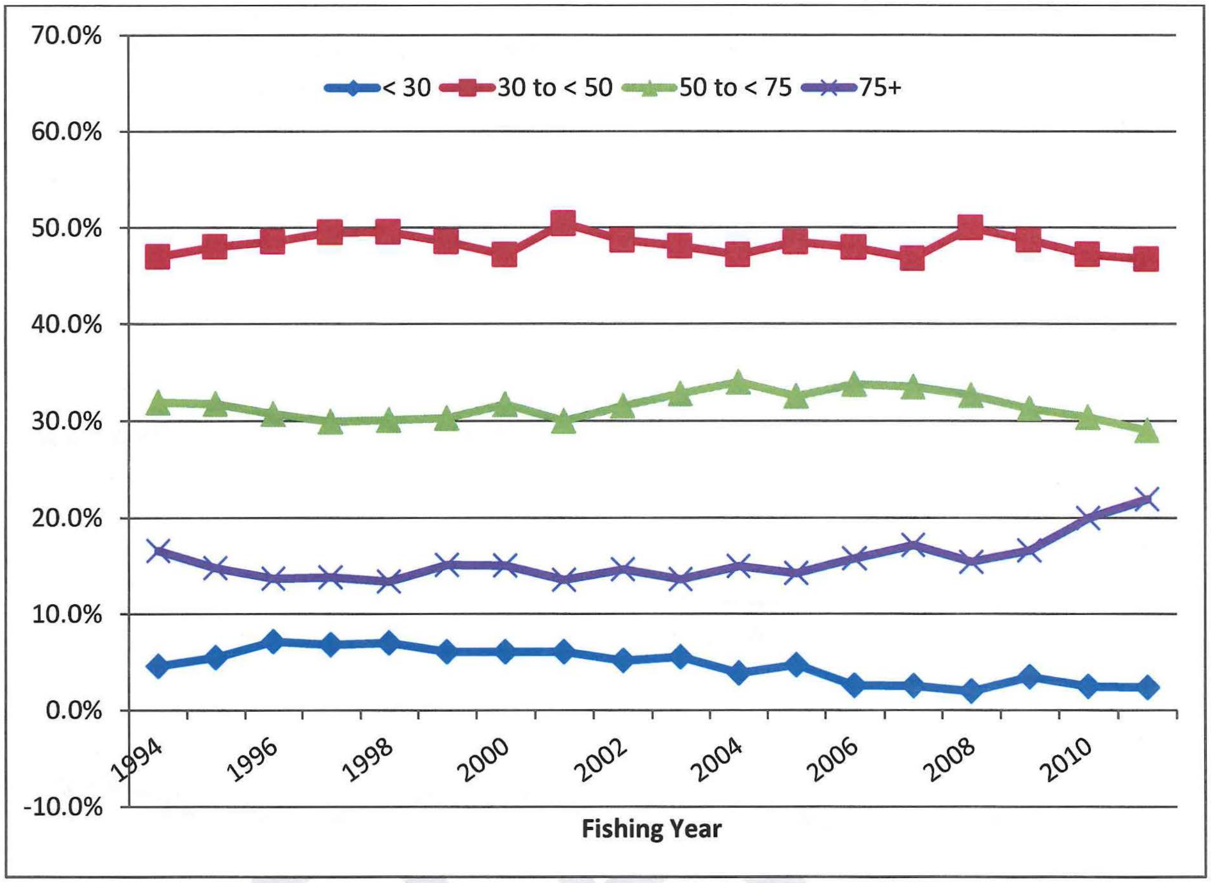

Figure 11. Shannon Diversity Index Share by Vessel Size Class for Limited Access Vessel Types That Landed Groundfish

The majority of vessel types were classified as having landed the majority of all species from inshore statistical areas (Figure 12). Inshore vessel types have accounted for between 75 and 80% of the Shannon diversity index in all years. More recently the proportion of the diversity index from offshore vessel types has increased from 19% in 2008 to 24.5% in 2011. This is consistent with the observed trend previously noted for vessels 75 feet or larger. This is also borne out when area fished is cross-referenced with vessel size (Figure 13). The relative contribution of both larger inshore vessel types and offshore vessel types has increased over the most recent 3-4 fishing years. Specifically, the contribution to the Shannon index made by large offshore vessel increased from 10% in 2008 to 15% in 2011 while the share of the index attributable to large inshore vessel types increased from 4.1% in 2009 to 6.9% in 2011. Note, however, the 2011 share from large inshore vessel types is not outside the range of historic data. For example, large inshore vessels accounted for almost 7% of the diversity index during fishing years 1994-2002.

Inshore vessels types that are 30 to less than 50 feet have remained the dominant vessel type without any notable trend averaging about 46% from 1994-2011. For the most part, the increasing trend in the relative contribution to the diversity index made by large vessels has been offset by a declining trend in the proportion of the index made up by inshore vessels between 50 and 75 feet. The share of the Shannon index by these vessels averaged 23% from 1994 to 2008 but has since fallen to 21% of the index in 2011.

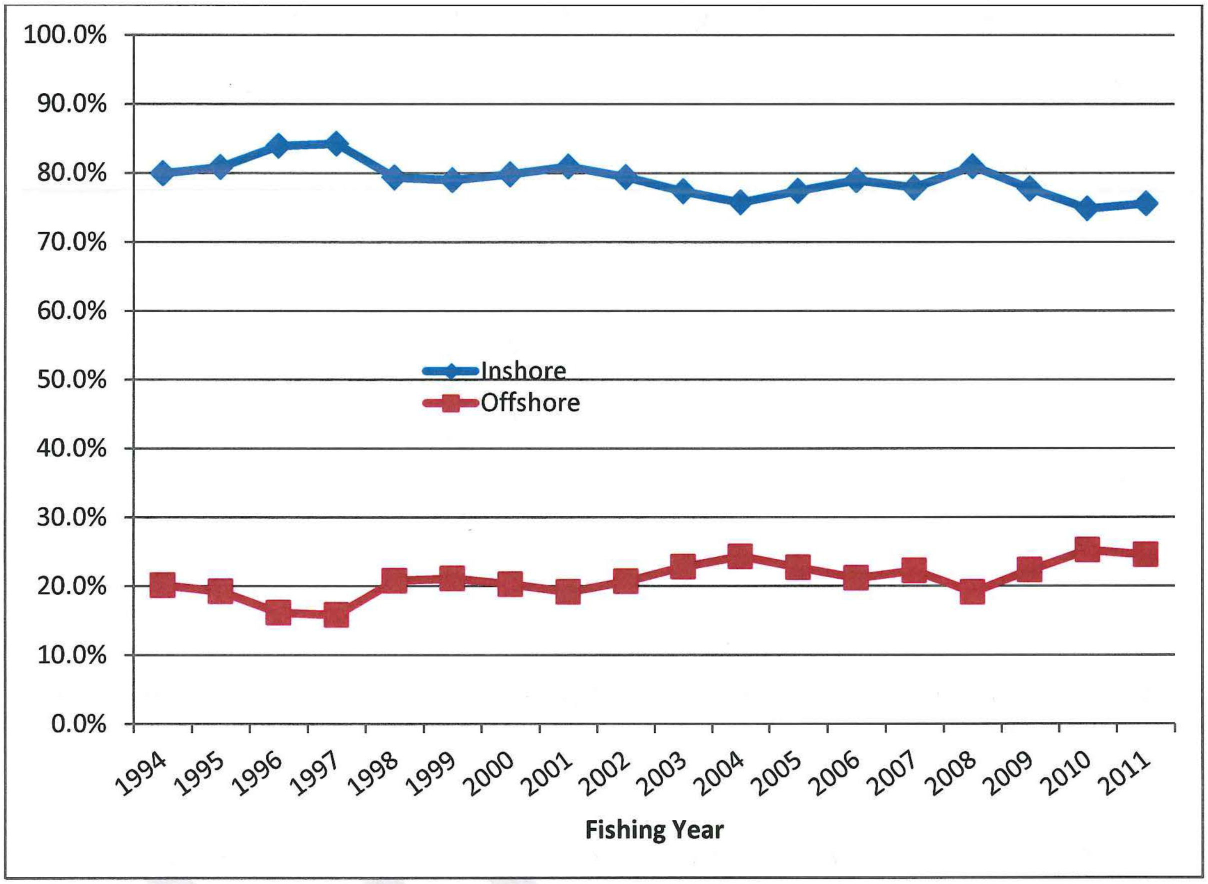

Figure 12. Shannon Diversity Index Shares by Area Fished for Limited Access Vessel Types that Landed Groundfish

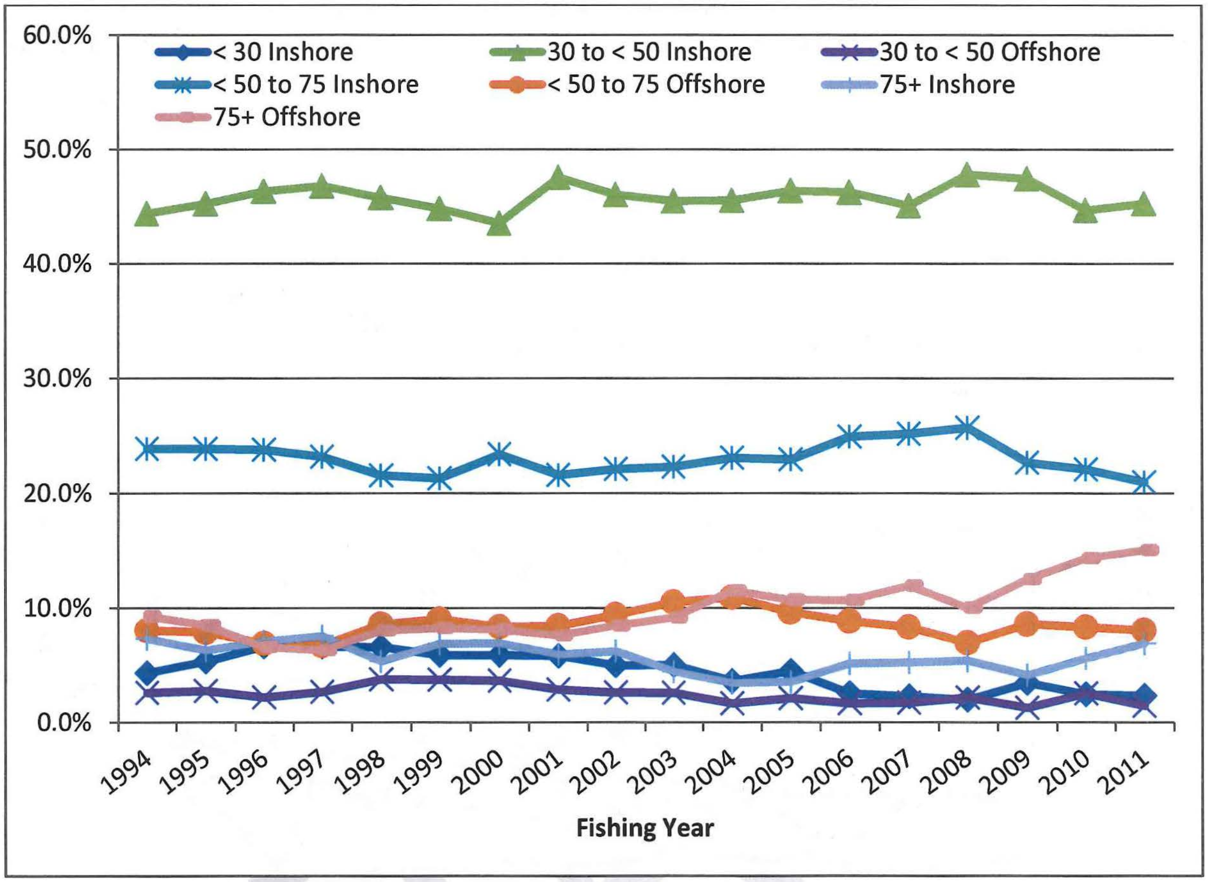

Figure 13. Shannon Diversity Index Shares by Area Fished and Vessel Size Class for Limited Access Vessel Types that Landed Groundfish

Partitioning the Shannon diversity index by state reveals a steep drop in the proportion of the index that is associated with vessel types in Maine regions. From 1994 to 2000 the proportion of the Shannon index from Maine-based vessel types was stable averaging approximately 17% of the index. In 2001 the Maine vessel type share began to decline, but at a comparatively gradual rate of 1.3% through 2005. After 2005, however, the contribution to the Shannon index dropped considerably from 15.8% in 2005 to 9.9% in 2010. The Shannon index share for limited access vessel types that landed groundfish was higher in 2011 (11.3%), but was still well below levels in years prior to 2005.

The majority of the reduction in Maine-based vessel types took place during 2006, 2007, and 2008 as the contribution to the total fleet diversity index declined by an average of 13.4% per year. This sharp decline was due to two interrelated factors. First, the overall decline in the total number of vessels classified as being in a Maine region at a faster rate than the fleet as a whole. As noted earlier the total fleet size of limited access vessels that landed groundfish declined by 67% from 1994 to 2011, but the Maine component of that fleet declined by almost 80%. The Maine component of the fleet declined at a slightly higher rate (4.8%) than the fleet as a whole (3.8%) from 1994 to 2004. This means that the relative share of Maine vessel types was declining at a faster rate than vessel types from other states accounting for the noted gradual decline in the proportional contribution to the Shannon diversity index at least until 2005.

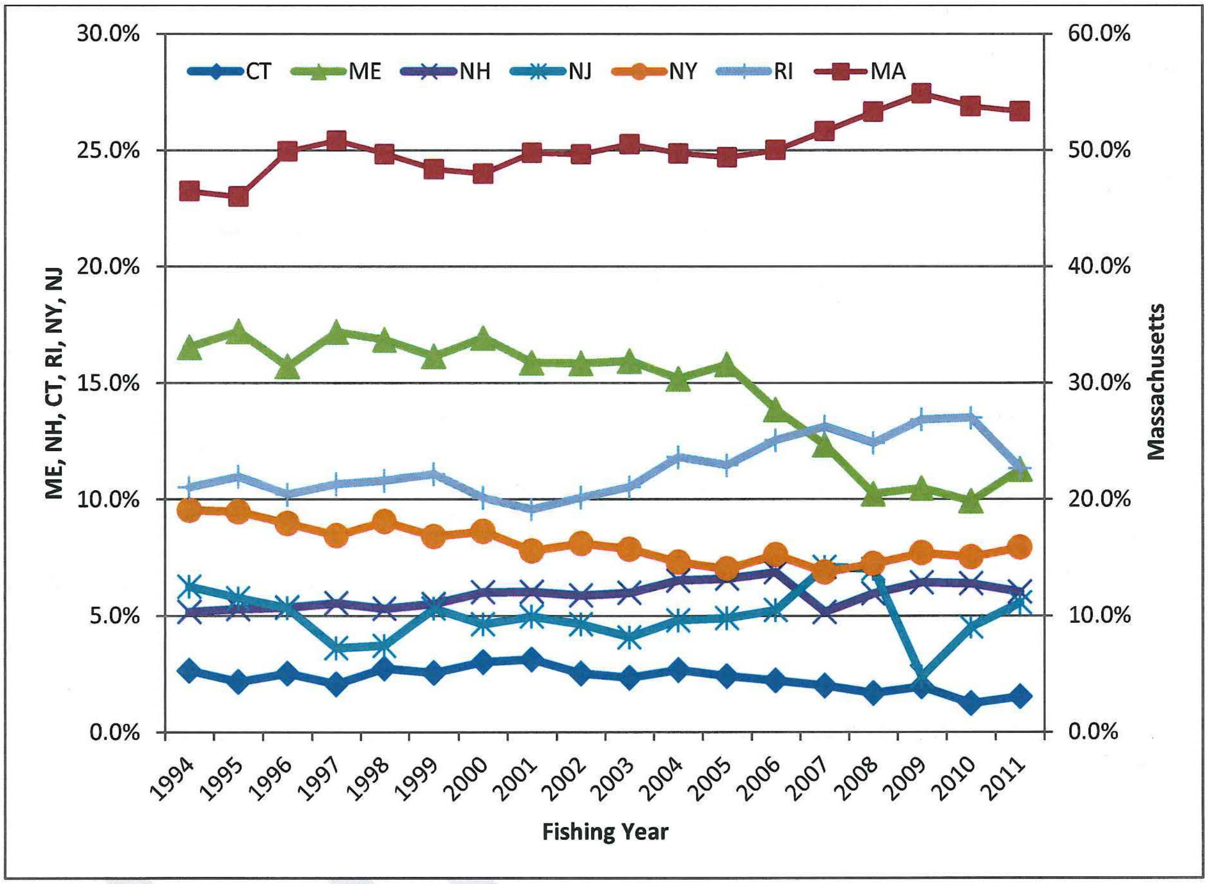

Figure 14. Shannon Diversity Index Shares by Region State for Limited Access Vessel Types that Landed Groundfish

From 2005 through 2010 both the Maine-based fleet and the groundfish fleet as a whole declined at a much faster rate than in prior years. The limited access fleet landing groundfish declined at an average annual rate of 11.2%, but the Maine fleet component declined at an average rate of 19.1%. At least part of this higher rate of decline in the Maine fleet was due to the disappearance of several vessel types in 2005, 2006, and 2007 that had historically accounted for about 10% of the total Maine fleet, at least as that fleet has been defined in this study. These vessel types include 1) offshore trawl vessels from 50 to < 75 feet, 2) offshore trawl vessels greater than 75 feet, and 3) inshore longline vessels 30 to < 50 feet. Each of these vessel types were classified as having landed the majority of groundfish trip landings in the Lower Mid-Coast region of Maine which includes Portland, ME. Note that this does not necessarily mean that these vessel types do not land any groundfish in the Lower Mid-Coast region, or for that matter, in any Maine port. It only means that these vessel types landed the majority of groundfish elsewhere.

Although the relative shift in Maine-based vessel types was larger than elsewhere the overall decline in fleet diversity means that there were declines in vessel types in other states as well. Based on the decision rules adopted herein there were a total of 279 unique vessel types indentified based on vessel size, gear, region of landing, and inshore/offshore area fished. As previously noted, 45 of these vessel types were present in every year leaving 234 vessel types that were present in 17 or fewer years from 1994-2011. A substantial number of these "transient" vessel types were present on only a few occasions while others were present in the majority of years. The former may be an artifact of the razor's edge decision rules which may have resulted in some artificial vessel types that may or may not represent a loss in fleet diversity. To further refine evaluation of losses in fleet diversity, vessel types were limited to the primary groundfish gears (bottom longline, rod & reel, gillnet, and trawl) that were present in at least 10 years or were present in fewer than 9 years, but were present at any time for at least 5 consecutive years. These criteria resulted in 64 vessel types that are likely to have been part of the limited access groundfish fleet whose loss would represent a meaningful reduction in fleet diversity. This does not necessarily mean that the 170 vessel types that did not meet these criteria do not contribute to fleet diversity. However, there is substantially greater uncertainty regarding whether these less frequent vessel types were "real" and which were artificially created by the vessel classification decision rules.

The 64 vessel types that used groundfish gear and were present according to the criteria noted above were further subdivided into categories based on whether they were intermittently present or present for consecutive years then no longer present. There were 21 vessel types that were 1) not present in 2011, 2) were present for 5 or more consecutive years, and 3) the last year present and the last year of consecutive presence was in the same year (Table 8). For each vessel type the number of years present from 1994-2004 is reported in column 5 and the last year present is reported in column 6. The beginning and ending year over which the vessel type was present is noted in column 7 while the minimum and maximum number of vessels over all years is reported in columns 8 and 9 respectively. Note the minimum number of vessels for each vessel type was usually associated with the last few consecutive years while the maximum number of vessels was typically associated with earlier years. Both Maine and Massachusetts lost the same number of vessel types (7), although the number of vessel types lost in any one region was largest (5) in the Lower Mid-Coast region of Maine with the Gloucester, North Shore region of Massachusetts not far behind (4).

Table 8. Limited Access Vessel Types that Landed Groundfish that are No Longer Present in The Fleet

Region	Area Fished	Gear	Size Category	Years Present	Last Year Present	Consecutive Years Present	Minimum Number of Vessels	Maximum Number of Vessels
Upper Mid-Coast, ME	Offshore	Trawl	30 to < 50	7	2003	1997-2003	1	5
	Offshore	Trawl	50 to < 75	7	2003	1997-2003	1	4
Lower Mid-Coast, ME	Offshore	Trawl	75+	14	2007	1994-2007	3	11
	Offshore	Trawl	50 to < 75	13	2006	1994-2006	2	17
	Inshore	Longline	30 to < 50	11	2005	1997-2005	1	5
	Inshore	Trawl	75+	11	2004	1994-2004	2	8
	Offshore	Rod & Reel	75+	6	1999	1994-1999	1	2
NH Seacoast	Offshore	Gillnet	30 to < 50	13	2006	1994-2006	1	6
	Offshore	Gillnet	50 to < 75	13	2006	1994-2006	1	4
Boston Area	Inshore	Longline	< 30	12	2005	1994-2005	1	4
Gloucester, North Shore	Inshore	Gillnet	< 30	12	2009	1999-2009	1	4
	Inshore	Gillnet	50 to < 75	12	2005	1994-2005	1	5
	Inshore	Longline	< 30	12	2005	1994-2005	1	6
	Inshore	Longline	50 to < 75	10	2003	1994-2003	1	4
New Bedford, South Shore	Inshore	Trawl	75+	17	2010	1994-2010	1	23
	Inshore	Trawl	50 to < 75	16	2009	1994-2009	3	38
Rhode Island	Inshore	Trawl	50 to < 75	17	2010	1994-2010	1	15
CT Seacoast	Inshore	Trawl	50 to < 75	17	2010	1994-2010	1	7
	Inshore	Gillnet	30 to < 50	16	2009	1994-2009	1	4
NY Coastal	Offshore	Trawl	50 to < 75	16	2009	1994-2009	1	10
NJ North	Inshore	Gillnet	30 to < 50	13	2006	1994-2006	1	9

There were 23 vessel types that were 1) not present in 2011, 2) were present for 5 or more consecutive years, and 3) were intermittently present in multiple years. Vessels meeting these three criteria tended to be present for several years disappear for one or more years then become present again for multiple years (Table 9). This intermittent pattern may be due to actual shifts in fishing patterns or to the classification decision rules which would make entry and exit of vessel types appear to more prevalent than they really are. Nevertheless, the majority of transient vessel types that were not present in 2011 were from the Cape & Islands region. All these vessel types were fixed gear and all but one were hook gear (rod & reel or bottom longline). In most cases the last year present for Cape & Islands vessel types was fishing year 2007.

There were 20 vessel types that 1) were not present in all years, 2) were present in at least 10 years or for at least 5 consecutive years, and 3) were present in 2011 (Table 10). In the majority of cases vessels listed in Table 10 have been intermittently present appearing disappearing and reappearing several times from 1994-2011. As noted above, this may reflect changes in fishing patterns or an artifact of the classification decision rules.

Table 9. Transient Vessel Types That Were Not Present in 2011								
Region	Area Fished	Gear	Size Category	Years Present	Last Year Present	Consecutive Years Present	Minimum Number of Vessels	Maximum Number of Vessels
Lower Mid-Coast, ME	Inshore	Rod/ Reel	30 to < 50	10	2006	1994-1997, 1999-2001, 2004-2006	1	3
	Offshore	Rod /Reel	50 to < 75	8	2003	1994-2000	1	4
Southern, ME	Inshore	Trawl	50 to < 75	16	2010	1994-2002, 2004-2010	1	3
	Inshore	Longline	30 to < 50	9	2008	1996-2002	1	2
NH Seacoast	Inshore	Longline	< 30	16	2010	1994-2007, 2009-2010	1	3
	Inshore	Gillnet	50 to < 75	13	2009	1994-1998, 2001-2002, 2004-2006	1	3
Gloucester, North Shore	Inshore	Longline	30 to < 50	14	2009	1994-2004, 2007-2009	1	12
	Offshore	Rod/Reel	50 to < 75	7	2002	1995-2000	1	1
Cape & Islands	Inshore	Rod/Reel	< 30	13	2007	1994-2005	1	6
	Offshore	Rod/Reel	30 to < 50	13	2010	1994-2001, 2008-2010	1	5
	Offshore	Longline	< 30	13	2007	1994-2005	1	3
	Inshore	Gillnet	50 to < 75	12	2007	1994-2004	1	2
	Offshore	Longline	30 to < 50	8	2002	1994-1999	1	4
New Bedford, South Shore	Inshore	Longline	< 30	11	2005	1994-2003	1	3
Rhode Island	Inshore	Gillnet	51 to < 75	15	2009	1994-2006, 2008-2009	1	4
	Inshore	Longline	30 to < 50	11	2010	1994-2003	1	6
CT Seacoast	Offshore	Trawl	75+	13	2009	1998-2006	1	3
	Inshore	Trawl	75+	11	2005	1994-2003	1	6
NY Coastal	Inshore	Longline	30 to < 50	14	2009	1994-2003, 2005-2006, 2008-2009	1	17
NJ North	Offshore	Trawl	50 to < 75	16	2010	1994-2008	1	9
NC Central	Inshore	Trawl	50 to < 75	16	2010	1994-2004, 2006-2010	1	5
	Inshore	Trawl	75+	14	2010	1994-2002, 2007-2010	1	4
	Offshore	Trawl	50 to < 75	12	2010	2000-2007	1	3

Table 10. Transient Vessel Types Present in Fishing Year 2011								
Region	Area Fished	Gear	Size Category	Years Present	Last Year Present	Consecutive Years Present	Minimum Number of Vessels	Maximum Number of Vessels
Upper Mid-Coast, ME	Inshore	Gillnet	30 to < 50	13	2011	1994-1999, 2001-2006	1	5
Lower Mid-Coast, ME	Offshore	Gillnet	50 to < 75	15	2011	1998-2007, 2010-2011	1	5
NH Seacoast	Inshore	Gillnet	< 30	14	2011	1994-2006	1	2
Boston Area	Inshore	Longline	30 to < 50	17	2011	1994-2009	1	13
Gloucester, North Shore	Offshore	Trawl	75+	17	2011	1994-2005, 2007-2011	2	9
	Offshore	Gillnet	30 to < 50	16	2011	2006-2009	1	6
	Offshore	Trawl	50 to < 75	16	2011	1997-2003, 2005-2011	1	6
New Bedford, South Shore	Inshore	Trawl	30 to < 50	11	2011	1994-1997, 2002-2003, 2006-2009	1	4
	Inshore	Gillnet	50 to < 75	10	2011	1995-1997, 2001-2001, 2009-2011	1	5
Rhode Island	Inshore	Gillnet	< 30	14	2011	1994-2002, 2007-2011	1	2
	Inshore	Longline	< 31	12	2011	1995-2000, 2002-2006	1	3
CT Seacoast	Inshore	Trawl	30 to < 50	17	2011	1994-2009	1	7
NY Coastal	Inshore	Rod & Reel	30 to < 50	16	2011	1994-2005, 2008-20011	1	5
	Inshore	Longline	< 30	15	2011	1994-2004, 2008-2011	1	4
	Inshore	Trawl	75+	12	2011	1994-2002, 2005-2006	1	10
	Offshore	Trawl	75+	17	2011	1994-2007, 2009-2011	1	10
NJ North	Inshore	Trawl	75+	17	2011	1994-2008, 2010-2011	1	5
	Offshore	Trawl	75+	14	2011	1994-1996, 1998-2001, 2003-2004, 2006-2008, 2010-2011	1	7
VA East	Offshore	Trawl	50 to < 75	7	2011	2002-2006, 2009	1	2
VA South	Offshore	Trawl	75+	12	2011	1994-1998, 2000-2001, 2003, 2006-2008	1	3