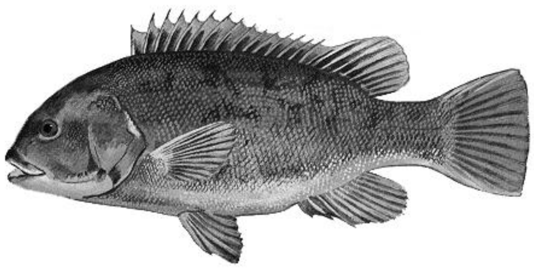
Chapter 12
Tautog



Tautoga onitis

INTRODUCTION

We aged a total of 134 tautog, *Tautoga onitis*, using their opercula collected by the VMRC's Biological Sampling Program in 2008. Of 134 aged fish, 120 and 14 fish were collected in Chesapeake Bay (bay fish) and the Atlantic waters (ocean fish) of Virginia, respectively. The average age of the bay fish was 4.3 years with a standard deviation of 1.3 and a standard error of 0.12. Seven age classes (2 to 8) were represented in the bay fish, comprising fish from the 2000 to 2006 year classes. The year class of 2004 (31%) was dominant in the bay fish sample in 2008 followed by the year classes of 2003 (28%). The average age for the ocean fish was 6.9 years with a standard deviation of 1.8 and a standard error of 0.48. Six age classes (age 3 and 5 to 9) were represented in the ocean fish, comprising fish from the 1999 to 2003, and 2005 year classes. We also aged a total of 129 fish using their otoliths in addition to ageing their opercula. The otolith ages were compared to the operculum ages to examine how close both ages were to one another (please see details in Results).

METHODS

Sample size for ageing — We estimated sample sizes for ageing tautog collected in both Chesapeake Bay and Atlantic waters of Virginia in 2008, respectively, using a two-stage random sampling method (Quinn and Deriso 1999) in order to increase precision in estimates of age composition from fish sampled efficiently and effectively. The basic equation is:

$$A = \frac{V_a}{\theta_a^2 CV^2 - B_a / L}, \qquad (1)$$

where A is the sample size for ageing tautog in 2008; θ_a stands for the proportion of age a fish in a catch. V_a and B_a represent variance components within and between length intervals for age a, respectively; CV is coefficient of variance; L is a subsample from a catch and used to estimate length distribution in the catch. θ_a, V_a, B_a, and CV were calculated using pooled age-length data of tautog collected from 2002 to 2007 and using equations in Quinn and Deriso (1999). For simplicity, the equations are not listed here. L was the total number of tautog used by VMRC to estimate length distribution of the caches from 2002 to 2007. The equation (1) indicates that the more fish that are aged, the smaller the CV (or higher precision) that will be obtained. Therefore, the criterion to decide A (number of fish) is that A should be a number above which there is only a 1% CV reduction achieved by aging an additional 100 or more fish.

Handling of collection — Sagittal otoliths (hereafter, refer to as "otoliths") and opercula were received by the Age & Growth Laboratory in labeled coin envelopes. Once in our hands, they were sorted based on date of capture, their envelope labels were verified against VMRC's collection data, and each fish assigned a unique Age and Growth Laboratory identification number. All otoliths and opercula were stored dry within their original labeled coin envelopes; otoliths were contained inside protective Axygen 2.0 ml microtubes.

Preparation —

Opercula Tautog opercula were boiled for several minutes to remove any attached skin and muscle tissue. After boiling, opercula were examined to determine whether they were collected whole or in some way damaged. Opercula were allowed to dry and finally stored in new labeled coin envelopes.

Otoliths Due to their fragility, we used our embedding and thin-sectioning method to prepare tautog otoliths for age determination. To start, a series of 14 mm x 5 mm x 3 mm wells (Ladd Industries silicon rubber mold) were pre-filled to half-volume with Loctite® 349 adhesive and permitted to cure for 24 hours until solidified. The wells were then filled to capacity with fresh, non-cured Loctite® 349 adhesive, at which point the otoliths could be inserted into the wells, suspended within a stable embedding atmosphere before sectioning. Otoliths were baked before embedment in the Loctite® 349 adhesive to produce better contrast of opaque and translucent zones within the matrix. Each otolith was baked in a Thermolyne 1400 furnace at 400°C for one to two minutes until it turned a medium brown color (caramel). The baked otoliths were inserted into the fresh Loctite® 349 adhesive, distal side up, with the long axis of the otolith exactly parallel with the long axis of the mold well. Once the otoliths were properly oriented, the mold was placed under UV light and left to solidify overnight. Once dry, each embedded otolith was removed from the mold and mounted with Crystalbond™ 509 adhesive. The otoliths were viewed by eye, and when necessary, under a stereo microscope to identify the location of the core, and the position of the core marked using a pencil across the otolith surface. At least one transverse cross-section (hereafter "thin-section) was then removed from the marked core of each otolith using a Buehler® IsoMet™ low-speed saw equipped with two, three inch diameter, Norton® Diamond Grinding Wheels, separated by a stainless steel spacer of 0.4mm (diameter 2.5"). The otolith was positioned so that the blades straddled each side of the focus marked by pencil. The glass slide was adjusted to ensure that the blades were exactly perpendicular to the long axis of the otolith. The otolith thin-section was viewed under a stereo microscope to determine which side (cut surface) of the otolith was closer to the focus. The otolith thin-section was mounted best-side up onto a glass slide with Flo-texx® mounting medium, which provided enhanced contrast and greater readability by increasing light transmission through the sections.

Readings — The CQFE system assigns an age class to a fish based on a combination of reading the information contained in its otolith, the date of its capture, and the species-specific period when it deposits its annulus. Each year, as the fish grows, its otoliths grow and leave behind markers of their age, called annuli. Technically, an otolith annulus is the combination of both the opaque and the translucent bands. In practice, only the opaque bands are counted as annuli. The number of these visible dark bands replaces "x" in our notation, and is the initial "age" assignment of the fish.

Second, the otolith section is examined for translucent growth. If no translucent growth is visible beyond the last dark annulus, the otolith is called "even" and no modification of the assigned age is made. The initial assigned age, then, is the age class of the fish. Any growth beyond the last annulus can be interpreted as either being toward the next age class or within the same age class. If translucent growth is visible beyond the last dark annulus, a "+" is added to the notation.

By convention all fish in the Northern Hemisphere are assigned a birth date of January 1. In addition, each species has a specific period during which it deposits the dark band of the annulus. If the fish is captured after the end of the species specific annulus deposition period and before January 1, it is assigned an age class notation of "x + x", where "x" is the number of dark bands in the otolith.

If the fish is captured between January 1 and the end of the species specific annulus deposition period, it is assigned an age class notation of "x + (x+1)". Thus, any growth beyond the last annulus, after its "birthday" but before the dark band deposition period, is interpreted as being toward the next age class.

For example, tautog otolith deposition occurs between May and July (Hostetter and Munroe 1993). A summer flounder captured between January 1 and July 31, before the end of the species' annulus formation period, with three visible annuli and some translucent growth after the last annulus, would be assigned an age class of "x + (x+1)" or 3 + (3+1), noted as 3 + 4. This is the same age-class assigned to a fish with four visible annuli captured after the end of July 31, the period of annulus formation, which would be noted as 4 + 4.

Tautog opercula are also considered to have a deposition period of May through July (Hostetter and Munroe 1993), and age class assignment using these hard-parts is conducted in the same way as otoliths.

All tautog samples (prepared opercula and sectioned otoliths) were aged by two different readers in chronological order based on collection date, without knowledge of previously estimated ages or the specimen lengths. Opercula were aged on a light table with no magnification (Figure 1).

Figure 1. Operculum from a 13 year-old male tautog.

All thin-sections were aged by two different readers using a Nikon SMZ1000 stereo microscope under transmitted light and dark-field polarization at between 8 and 20 times magnification (Figure 2).

Figure 2. Otolith section from a 13 year-old male tautog. Same fish as Figure 1.

When the readers' ages agreed, that age was assigned to the fish. When the two readers disagreed, both readers sat down together and re-aged the fish, again without any knowledge of previously estimated ages or lengths, and assigned a final age to the fish. When the readers were unable to agree on a final age, the fish was excluded from further analysis.

Comparison Tests — A symmetric test (Hoenig et al. 1995) and coefficient of variation (CV) analysis were used to detect any systematic difference and precision on age readings, respectively, for the following comparisons: 1) between the two readers in the current year; 2) within each reader in the current year; 3) time-series bias between the current and previous years within each reader; and 4) between operculum and otoliths ages. The readings from the entire sample for the current year were used to examine the difference between two readers. A random sub-sample of 50 fish from the current year was selected for second readings to examine the difference within a reader. Fifty otoliths randomly selected from fish aged in 2000 were used to examine the time-series bias within each reader. A figure of 1:1 equivalence was used to illustrate those differences (Campana et al. 1995). All statistics analyses and figures were made using R (R Development Core Team 2009).

RESULTS

We estimated a sample size of 393 for ageing the bay tautog in 2008, ranging in length interval from 9 to 25 inches (Table 1). This sample size provided a range in CV for age composition approximately from the smallest CV of 8% for age 3 to the largest CV of 25% for age 1 of the bay fish. We aged all 116 tautog who had both total lengths and opercula collected by VMRC in Chesapeake Bay in 2008. We fell short in our over-all collections for this optimal length-class sampling estimate by 277 fish from among the small, medium, and large length intervals (Table 1), as a result, the precision for the estimates of all age groups would be influenced significantly.

We estimated a sample size of 376 for ageing the ocean tautog in 2008, ranging in length interval from 8 to 30 inches (Table 2). This sample size provided a range in CV for age composition approximately from the smallest CV of 9% for age 5 to the largest CV of 25% for age 2 of the ocean fish. We aged all 14 tautog collected by VMRC in Atlantic waters of Virginia in 2008. We fell short in our over-all collections for this optimal length-class sampling estimate by 362 fish from among the small, medium, and large length intervals (Table 2), as a result, the precision for the estimates of all age groups would be influenced significantly.

Opercula — The measurement of reader self-precision was good for both readers. There is no significant difference between the first and second readings for Reader 1 with a CV of 3.5% and an agreement of 76% (test of symmetry: $\chi^2 = 8$, df = 8, $P = 0.4335$). There is no significant difference between the first and second readings for Reader 2 with a CV of 4.4% an agreement of 72% (test of symmetry: $\chi^2 = 12$, df = 9, $P = 0.2133$). There was no evidence of systematic disagreement between Reader 1 and Reader 2 with a CV of 5.2% an agreement of 70% (test of symmetry: $\chi^2 = 10.33$, df = 10, $P = 0.4118$) (Figure 3).

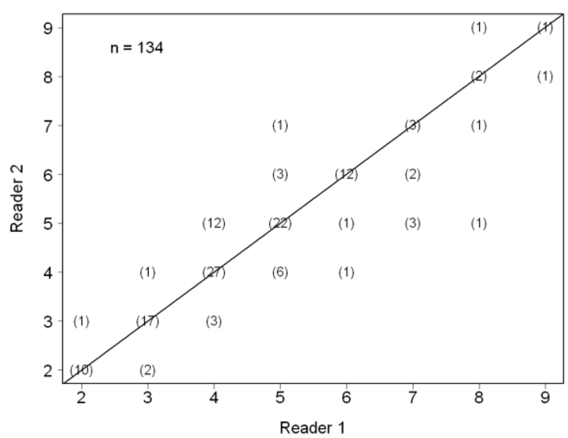


Figure 3. Between-reader comparison of operculum age estimates for tautog collected in Chesapeake Bay and Virginia waters of the Atlantic in 2008.

There is no time-series bias for both readers. The age readings of 58% fish by Reader 1 in 2008 had an agreement with those fish aged in 2003 with a CV of 6% (test of symmetry: $\chi^2 = 7.5$, df = 7, $P = 0.3787$). The age readings of 72% fish by Reader 2 in 2008 had an agreement with those fish aged in 2003 with a CV of 4.4% (test of symmetry: $\chi^2 = 11$, df = 9, $P = 0.2757$).

Of the 120 bay tautog aged with opercula, 7 age classes (2 to 8) were represented (Table 3). The average age for the sample was 4.3 years. The standard deviation and standard error were 1.3 and 0.12, respectively. Year-class data indicates that recruitment into the fishery in Chesapeake Bay begins at age 2, which corresponds to the 2006 year-class for tautog caught in 2008. The year class of 2004 (31%) tautog was dominated in the sample in 2008 followed by 2003 (28%). The sex ratio of male to female was 1:1.58 for the bay fish (Figure 4).

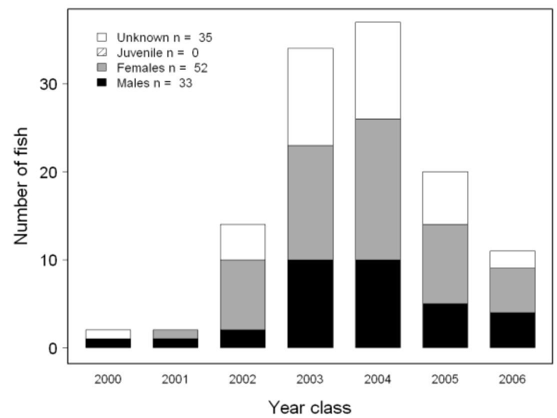


Figure 4. Year-class frequency distribution for tautog collected in Chesapeake Bay of Virginia for ageing in 2008. Distribution is broken down by sex and estimated using operculum ages. "Unknown" is used for specimen that were not eligible for gonad extraction, or, during sampling, the sex was not examined.

Of the 14 ocean tautog aged with opercula, 6 age classes (3, 5 to 9) were represented (Table 4). The average age for the sample was 6.9 years. The standard deviation and standard error were 1.8 and 0.48, respectively. Year-class data indicates that recruitment into the fishery in Atlantic waters of Virginia begins at age 3, which corresponds to the 2005 year-class for tautog caught in 2008. The sex ratio of male to female was 1:2.5 for the ocean fish (Figure 5).

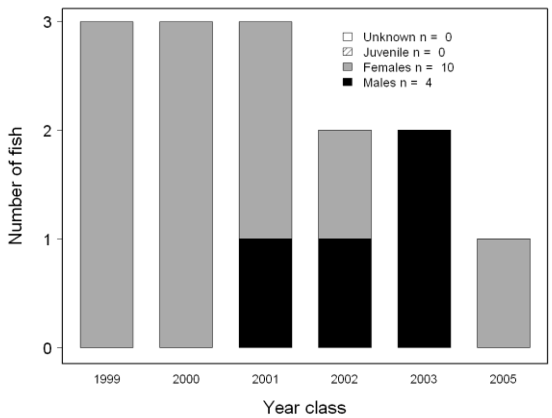


Figure 5. Year-class frequency distribution for tautog collected in Virginia waters of Atlantic for ageing in 2008. Distribution is broken down by sex and estimated using operculum ages. “Unknown” is used for specimen that were not eligible for gonad extraction, or, during sampling, the sex was not examined.

Otoliths — The measurement of reader self-precision was very good for both readers. There is no significant difference between the first and second readings for Reader 1 with a CV of 1.4% and an agreement of 92% (test of symmetry: $\chi^2 = 4$, df = 4, $P = 0.4060$). There is no significant difference between the first and second readings for Reader 2 with a CV of 2.5% and an agreement of 84% (test of symmetry: $\chi^2 = 6$, df = 6, $P = 0.4232$). There was no evidence of systematic disagreement between Reader 1 and Reader 2 with an agreement of 95% and a CV of 0.9% (test of symmetry: $\chi^2 = 7$, df = 5, $P = 0.2206$) (Figure 6).

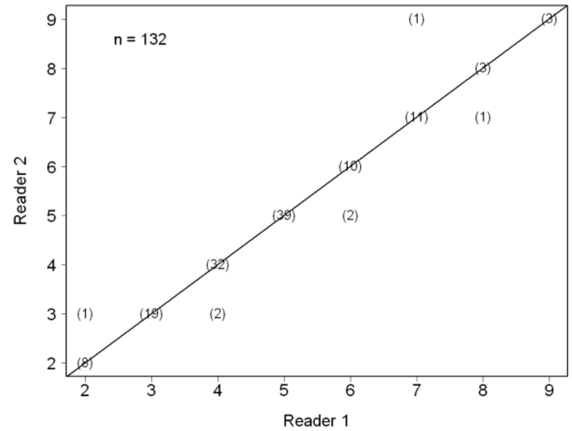


Figure 6. Between-reader comparison of otolith age estimates for tautog collected in Chesapeake Bay and Virginia waters of Atlantic in 2008.

There is no time-series bias for both readers. Reader 1 had an agreement of 92% with the fish aged in 2003 with a CV of 1% (test of symmetry: $\chi^2 = 4$, df = 2, $P = 0.1353$). Reader 2 had an agreement of 88% with the fish aged in 2003 with a CV of 1.3% (test of symmetry: $\chi^2 = 3.33$, df = 2, $P = 0.1889$).

Of 129 fish aged with otoliths, 8 age classes (2 to 9) were represented. The average age for the sample was 4.7 years. The standard deviation and standard error were 1.6 and 0.14, respectively.

Comparison of Operculum and Otolith Ages — We aged 128 tautog using both their opercula and otoliths. There was no evidence of systematic disagreement between otolith and operculum ages (test of symmetry: $\chi^2 = 12.29$, df = 11, $P = 0.3426$) with an average CV of 7.3%. There was an agreement of 64% between operculum and otolith ages whereas opercula were assigned a lower and higher age than otoliths for 23% and 13% of the fish, respectively (Figure 7). There was also no evidence of bias between otolith and operculum ages using an age bias plot (Figure 8).

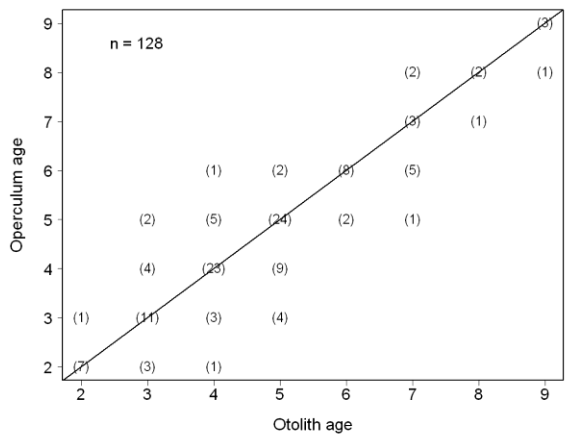


Figure 7. Comparison operculum and otolith age estimates for tautog collected in Chesapeake Bay and Virginia waters of the Atlantic in 2008.

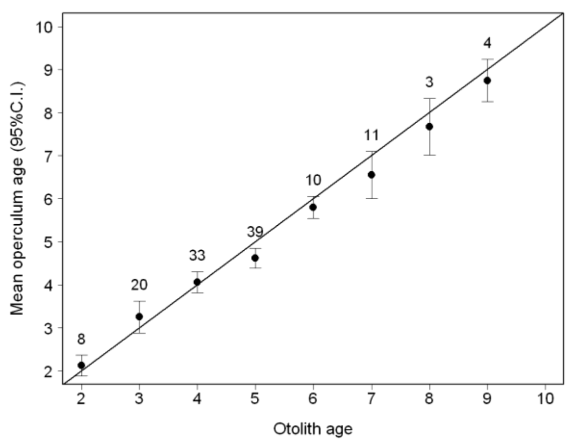


Figure 8. Age-bias plot for tautog operculum and otolith age estimates in 2008.

Age-Length-Key(ALK) — We developed an ALK for both bay (Table 5) and ocean fish (Table 6) using operculum ages, separately. Due to the small samples collected in 2008, we don't recommend to use the ALKs to do the conversion of numbers-at-length in the estimated catch to numbers-at-age.

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Table 1. Number of tautog collected in the Chesapeake Bay of Virginia in 2008 and operculum-aged in each 1-inch length interval. “Target” represents the sample size for ageing estimated for 2008, "Collected" represents number of fish with both total length and otoliths, and “Need” represents number of fish that were not obtained in each length interval compared to the optimum sample size for ageing and number of fish aged. There were 2 fish without opercula.

Interval	Target	Collected	Aged	Need
9 - 9.99	5	0	0	5
10 - 10.99	5	0	0	5
11 - 11.99	9	0	0	9
12 - 12.99	10	3	3	7
13 - 13.99	54	10	10	44
14 - 14.99	83	27	26	57
15 - 15.99	66	29	29	37
16 - 16.99	49	20	20	29
17 - 17.99	40	14	14	26
18 - 18.99	25	8	8	17
19 - 19.99	14	3	3	11
20 - 20.99	8	2	2	6
21 - 21.99	5	0	0	5
22 - 22.99	5	1	0	5
23 - 23.99	5	1	1	4
24 - 24.99	5	0	0	5
25 - 25.99	5	0	0	5
Totals	393	118	116	277

Table 2. Number of tautog collected in Virginia waters of Atlantic in 2008 and operculum-aged in each 1-inch length interval. “Target” represents the sample size for ageing estimated for 2008, "Collected" represents number of fish with both total length and otoliths, and “Need” represents number of fish that were not obtained in each length interval compared to the optimum sample size for ageing and number of fish aged.

Interval	Target	Collected	Aged	Need
8 - 8.99	5	0	0	5
9 - 9.99	5	0	0	5
10 - 10.99	5	0	0	5
11 - 11.99	10	0	0	10
12 - 12.99	8	0	0	8
13 - 13.99	49	0	0	49
14 - 14.99	56	0	0	56
15 - 15.99	52	0	0	52
16 - 16.99	46	2	2	44
17 - 17.99	36	2	2	34
18 - 18.99	29	5	5	24
19 - 19.99	18	2	2	16
20 - 20.99	18	2	2	16
21 - 21.99	10	0	0	10
22 - 22.99	7	1	1	6
23 - 23.99	7	0	0	7
24 - 24.99	5	0	0	5
25 - 25.99	5	0	0	5
30 - 30.99	5	0	0	5
Totals	376	14	14	362

Table 3. The number of tautog assigned to each total length-at-age category for 116 fish sampled for operculum age determination in Chesapeake Bay of Virginia during 2008.

	Age							
Interval	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**Totals**
12 - 12.99	1	1	1	0	0	0	0	3
13 - 13.99	3	3	3	1	0	0	0	10
14 - 14.99	7	11	7	1	0	0	0	26
15 - 15.99	0	4	10	10	5	0	0	29
16 - 16.99	0	1	7	9	3	0	0	20
17 - 17.99	0	0	4	9	1	0	0	14
18 - 18.99	0	0	1	4	2	0	1	8
19 - 19.99	0	0	1	0	1	1	0	3
20 - 20.99	0	0	0	0	0	1	1	2
23 - 23.99	0	0	0	0	1	0	0	1
Totals	11	20	34	34	13	2	2	116

Table 4. The number of tautog assigned to each total length-at-age category for 14 fish sampled for operculum age determination in Virginia waters of Atlantic during 2008.

	Age						
Interval	**3**	**5**	**6**	**7**	**8**	**9**	**Totals**
16 - 16.99	1	0	0	0	1	0	2
17 - 17.99	0	1	0	0	1	0	2
18 - 18.99	0	0	1	2	0	2	5
19 - 19.99	0	1	0	0	1	0	2
20 - 20.99	0	0	1	0	0	1	2
22 - 22.99	0	0	0	1	0	0	1
Totals	1	2	2	3	3	3	14

Table 5. Age-Length key, as proportion-at-age in each 1-inch length interval, based on operculum ages for tautog sampled in Chesapeake Bay of Virginia during 2008.

	Age						
Interval	**2**	**3**	**4**	**5**	**6**	**7**	**8**
12 - 12.99	0.333	0.333	0.333	0	0	0	0
13 - 13.99	0.3	0.3	0.3	0.1	0	0	0
14 - 14.99	0.269	0.423	0.269	0.038	0	0	0
15 - 15.99	0	0.138	0.345	0.345	0.172	0	0
16 - 16.99	0	0.05	0.35	0.45	0.15	0	0
17 - 17.99	0	0	0.286	0.643	0.071	0	0
18 - 18.99	0	0	0.125	0.5	0.25	0	0.125
19 - 19.99	0	0	0.333	0	0.333	0.333	0
20 - 20.99	0	0	0	0	0	0.5	0.5
23 - 23.99	0	0	0	0	1	0	0

Table 6. Age-Length key, as proportion-at-age in each 1-inch length interval, based on operculum ages for tautog sampled in Virginia waters of Atlantic during 2008.

	Age					
Interval	**3**	**5**	**6**	**7**	**8**	**9**
16 - 16.99	0.5	0	0	0	0.5	0
17 - 17.99	0	0.5	0	0	0.5	0
18 - 18.99	0	0	0.2	0.4	0	0.4
19 - 19.99	0	0.5	0	0	0.5	0
20 - 20.99	0	0	0.5	0	0	0.5
22 - 22.99	0	0	0	1	0	0