The adequacy of aging techniques in vertebrates for rapid estimation of population mortality rates from age distributions

Zhao, M.; Klaassen, C.A.J.; Lisovski, S.; Klaassen, M.

DOI
10.1002/ece3.4854

Publication date
2019

Document Version
Other version

Published in
Ecology and Evolution

License
CC BY

Citation for published version (APA):
Zhao, M., Klaassen, C. A. J., Lisovski, S., & Klaassen, M. (2019). The adequacy of aging techniques in vertebrates for rapid estimation of population mortality rates from age distributions. Ecology and Evolution, 9(3), 1394-1402. https://doi.org/10.1002/ece3.4854
Appendix S4. $R^2$ and $|\beta/\sigma|$ for case studies employing eight different aging techniques (telomere length, racemization, DNA methylation, signal-joint T-cell Recombination Excision Circle (sjTREC), otolith ring count, otolithometry, age-length keys and skeletochronology) in vertebrates.

| Indicator            | Taxa       | Species       | Latin name    | $R^2$ | $|\beta/\sigma|$ | Reference                  |
|----------------------|------------|---------------|---------------|-------|------------------|----------------------------|
| Telomere length      | Human      | Human         | Homo sapiens  | 0.56  | 0.08             | (Takasaki et al., 2003)    |
|                      | Human      | Human         | Homo sapiens  | 0.69  | 0.07             | (Tsuji et al., 2002)       |
|                      | Human      | Human         | Homo sapiens  | 0.09  | 0.04             | (Unryn et al., 2005)       |
|                      | Human      | Human         | Homo sapiens  | 0.26  | 0.03             | (Lahnert, 2005)            |
|                      | Human      | Human         | Homo sapiens  | 0.31  | 0.02             | (Unryn et al., 2005)       |
|                      | Human      | Human         | Homo sapiens  | 0.22  | 0.02             | (Lahnert, 2005)            |
|                      | Human      | Human         | Homo sapiens  | 0.18  | 0.01             | (Allsopp et al., 1992)     |
|                      | Human      | Human         | Homo sapiens  | 0.30  | 0.02             | (Lindsey et al., 1991)     |
|                      | Human      | Human         | Homo sapiens  | 0.29  | 0.02             | (Melk et al., 2000)        |
|                      | Human      | Human         | Homo sapiens  | 0.25  | 0.03             | (Hastie et al., 1990)      |
|                      | Human      | Human         | Homo sapiens  | 0.40  | 0.03             | (Furugori et al., 2000)    |
|                      | Human      | Human         | Homo sapiens  | 0.36  | 0.04             | (Kang et al., 2002)        |
| Species                  | Genus and Species            | N1  | N2  | Reference                      |
|-------------------------|------------------------------|-----|-----|-------------------------------|
| Human                   | Homo sapiens                 | 0.60| 0.04| (Yang et al., 2001)           |
| Human                   | Homo sapiens                 | 0.35| 0.05| (Wiemann et al., 2002)        |
| Mammal                  | Dog                          | 0.02| 0.04| (Nasir et al., 2001)          |
| Mammal                  | Dog                          | 0.02| 0.03| (Nasir et al., 2001)          |
| Mammal                  | Donkey                       | 0.17| 0.05| (Argyle et al., 2003)         |
| Mammal                  | Cynomolgus monkey            | 0.27| 0.06| (Lee et al., 2002)            |
| Mammal                  | Dog                          | 0.47| 0.42| (Yazawa et al., 2001)         |
| Mammal                  | Horse                        | 0.64| 0.15| (Katepalli et al., 2008)      |
| Mammal                  | Japanese Black cattle        | 0.62| 0.24| (Miyashita et al., 2002)      |
| Mammal                  | Sheep                        | 0.39| 0.42| (Shiels et al., 1999)         |
| Bird                    | Zebra finch                  | 0.54| 1.60| (Haussmann and Vleck, 2002)   |
| Bird                    | Zebra finch                  | 0.82| 1.52| (Haussmann and Mauck, 2008)   |
| Bird                    | Tree swallow                 | 0.34| 0.36| (Haussmann et al., 2003b)     |
| Bird                    | Adelie penguin               | 0.55| 0.30| (Haussmann et al., 2003b)     |
| Bird                    | European shag                | 0.00| 0.01| (Hall et al., 2004)           |
| Bird                    | Common tern                  | 0.61| 0.17| (Haussmann et al., 2003a)     |
| Bird                    | Leach’s storm-petrel          | 0.66| 0.14| (Haussmann et al., 2003b)     |
| Species                      | Scientific Name         | Percentage | Error | Reference                        |
|------------------------------|-------------------------|------------|-------|----------------------------------|
| Great frigatebird            | Fregata minor           | 0.74       | 0.10  | (Juola et al., 2006)             |
| Kakapo                       | Strigops habroptila     | 0.02       | 0.01  | (Horn et al., 2011)              |
| Kakapo                       | Strigops habroptila     | 0.00       | 0.01  | (Horn et al., 2011)              |
| Blue-footed booby            | Sula nebouxii           | 0.00       | 0.00  | (Foote, 2008)                    |
| American redstart            | Setophaga ruticilla     | 0.29       | 0.00  | (Angelier et al., 2013)          |
| Thick-billed murre           | Uria lomvia             | 0.10       | 0.04  | (Young et al., 2013)             |
| Alpine swift                 | Apus melba              | 0.03       | 0.04  | (Bize et al., 2009)              |
| Wandering albatross          | Diomedea exulans        | 0.00       | 0.01  | (Hall et al., 2004)              |
| Giant petrel                 | Macronectes giganteus   | 0.62       | 0.10  | (Foote, 2008)                    |
| Giant petrel                 | Macronectes halli       | 0.43       | 0.10  | (Foote, 2008)                    |
| Thick-billed murre           | Uria lomvia             | 0.41       | 0.11  | (Young et al., 2013)             |
| Dunlin                       | Calidris alpina         | 0.12       | 0.11  | (Pauliny et al., 2006)           |
| Sand martin                  | Riparia riparia         | 0.34       | 0.29  | (Pauliny et al., 2006)           |
| Fish                         | Japanese black porgy    | 0.33       | 0.66  | (Tsui, 2005)                     |
| Medaka                       | Oryzias latipes         | 0.33       | 0.64  | (Hatakeyama et al., 2008)        |
| Common carp                  | Cyprinus carpio         | 0.80       | 0.54  | (Izzo, 2010)                     |
| Common carp                  | Cyprinus carpio         | 0.73       | 0.51  | (Izzo, 2010)                     |
| Species                          | Scientific Name               | Min | Max | Reference          |
|---------------------------------|-------------------------------|-----|-----|--------------------|
| Japanese black porgy            | Acanthopagrus schlegeli      | 0.06| 0.35|(Tsui, 2005)      |
| Common carp                     | Cyprinus carpio               | 0.09| 0.12|(Izzo, 2010)      |
| Common carp                     | Cyprinus carpio               | 0.00| 0.02|(Izzo, 2010)      |
| European sea bass               | Dicentrarchus labrax          | 0.03| 0.01|(Horn et al., 2008) |
| Golden perch                    | Macquaria ambigua             | 0.01| 0.07|(Izzo, 2010)      |
| Mangrove red snapper            | Lutjanus argentimaculatus    | 0.15| 0.34|(Tsui, 2005)      |
| Bluefin leatherjacket           | Thammaconus degeni            | 0.75| 0.43|(Izzo, 2010)      |
| Mangrove red snapper            | Lutjanus argentimaculatus    | 0.25| 0.47|(Tsui, 2005)      |
| Australasian snapper            | Chrysophyrys auratus          | 0.80| 0.50|(Izzo, 2010)      |
| Mangrove red snapper            | Lutjanus argentimaculatus    | 0.38| 0.51|(Tsui, 2005)      |
| Japanese black porgy            | Acanthopagrus schlegeli      | 0.21| 0.56|(Tsui, 2005)      |
| Sand flathead                   | Platyecephalus bassensis     | 0.74| 0.62|(Izzo, 2010)      |
| Japanese black porgy            | Acanthopagrus schlegeli      | 0.18| 0.81|(Tsui, 2005)      |
| Bluespotted goatfish            | Upeneichthys vlamingii       | 0.85| 1.02|(Izzo, 2010)      |
| Reptile                         |                               |     |     |                    |
| Water python                    | Liasis fuscus                 | 0.00| 0.02|(Ujvari and Madsen, 2009) |
| Water python                    | Liasis fuscus                 | 0.01| 0.02|(Ujvari and Madsen, 2009) |
| Loggerhead turtle               | Caretta caretta               | 0.09| 0.02|(Hatase et al., 2008) |
| Species                        | Species Name                      | Ref1  | Ref2  | Ref3  |
|-------------------------------|-----------------------------------|-------|-------|-------|
| Loggerhead turtle             | Caretta caretta                   | 0.00  | 0.01  | (Hatase et al., 2008) |
| Sand lizard                   | Lacerta agilis                    | 0.12  | 0.37  | (Olsson et al., 2011) |
| Garter snake                  | Thamnophis elegans                | 0.73  | 0.46  | (Bronikowski, 2008)   |
| Shark                         | Port Jackson shark                | 0.03  | 0.04  | (Izzo, 2010)          |
|                               | Port Jackson shark                | 0.10  | 0.05  | (Izzo, 2010)          |
| DNA methylation               | Human H. sapiens                  | 0.82  | 0.15  | (Lee et al., 2015)    |
|                               | Human H. sapiens                  | 0.95  | 0.21  | (Bekaert et al., 2015) |
|                               | Human H. sapiens                  | 0.86  | 0.15  | (Zbiec-Piekarska et al., 2015) |
|                               | Human H. sapiens                  | 0.69  | 0.13  | (Bocklandt et al., 2011) |
|                               | Human H. sapiens                  | 0.93  | 0.26  | (Hannum et al., 2013) |
|                               | Human H. sapiens                  | 0.06  | 0.02  | (Christensen et al., 2009) |
|                               | Human H. sapiens                  | 0.98  | 0.23  | (Weidner et al., 2014) |
|                               | Human H. sapiens                  | 0.65  | 0.08  | (Koch and Wagner, 2011) |
|                               | Human H. sapiens                  | 0.79  | 0.15  | (Horvath et al., 2014) |
| Mammal                        | Mouse Mus musculus                | 0.93  | 0.27  | (Maegawa et al., 2010) |
|                               | Bonobo Pan paniscus               | 0.71  | 0.37  | (Horvath, 2013)       |
|                               | Gorilla Gorilla beringei graueri | 0.00  | 0.00  | (Horvath, 2013)       |
| sjTREC          | Species       | Genus       | Species          | GC-content | UV-score | Reference                   |
|-----------------|---------------|-------------|------------------|------------|----------|-----------------------------|
| Humpback whale  | Megaptera      | novaeangliae| 0.79 0.21        | (Polanowski et al., 2014) |
| Human           | Homo sapiens  | 0.67 2.38   | (Ou et al., 2011) |
| Human           | Homo sapiens  | 0.65 0.18   | (Cho et al., 2014) |
| Human           | Homo sapiens  | 0.76 0.76   | (Ou et al., 2012) |
| Human           | Homo sapiens  | 0.77 0.76   | (Qu et al., 2013) |
| Human           | Homo sapiens  | 0.84 0.10   | (Zubakov et al., 2010) |
| Human           | Homo sapiens  | 0.85 0.11   | (Douek et al., 1998) |
| Mammal          | Canis familiaris | 0.00 0.00 | (Ito et al., 2015) |
| Racemization    | Human         | Homo sapiens| 0.96 2.39        | (Ohtani, 1994) |
| Human           | Homo sapiens  | 0.88 1.58   | (Ohtani, 1994) |
| Human           | Homo sapiens  | 0.98 1.42   | (Ohtani and Yamamoto, 1991) |
| Human           | Homo sapiens  | 0.99 0.91   | (Ohtani and Yamamoto, 2010) |
| Human           | Homo sapiens  | 0.99 0.82   | (Ohtani et al., 1995) |
| Human           | Homo sapiens  | 0.99 0.81   | (Ohtani et al., 1995) |
| Human           | Homo sapiens  | 0.86 0.80   | (Ohtani, 1994) |
| Human           | Homo sapiens  | 0.99 0.44   | (Ohtani et al., 1995) |
| Species         | Species         | Value1 | Value2 | Reference                        |
|----------------|----------------|--------|--------|----------------------------------|
| Human          | Homo sapiens   | 0.99   | 0.53   | (Ohtani et al., 1995)            |
| Human          | Homo sapiens   | 0.87   | 0.80   | (Ohtani, 1994)                   |
| Human          | Homo sapiens   | 0.99   | 0.78   | (Ohtani and Yamamoto, 2010)      |
| Human          | Homo sapiens   | 0.98   | 0.61   | (Ohtani et al., 1995)            |
| Human          | Homo sapiens   | 0.99   | 0.70   | (Ohtani et al., 1995)            |
| Human          | Homo sapiens   | 0.97   | 0.69   | (Ohtani and Yamamoto, 2010)      |
| Human          | Homo sapiens   | 0.99   | 0.65   | (Ohtani and Yamamoto, 1987)      |
| Human          | Homo sapiens   | 0.99   | 0.64   | (Ohtani and Yamamoto, 1992)      |
| Human          | Homo sapiens   | 0.98   | 0.63   | (Ohtani and Yamamoto, 2010)      |
| Human          | Homo sapiens   | 0.98   | 0.56   | (Ohtani, 1995)                   |
| Human          | Homo sapiens   | 0.98   | 0.43   | (Ohtani et al., 1995)            |
| Human          | Homo sapiens   | 0.68   | 0.52   | (Ohtani, 1994)                   |
| Human          | Homo sapiens   | 0.98   | 0.50   | (Ohtani and Yamamoto, 2011)      |
| Human          | Homo sapiens   | 0.97   | 0.29   | (Ohtani et al., 1995)            |
| Human          | Homo sapiens   | 0.98   | 0.44   | (Fu et al., 1995)                |
| Human          | Homo sapiens   | 0.98   | 0.43   | (Ohtani, 1995)                   |
| Human          | Homo sapiens   | 0.98   | 0.42   | (Ritz et al., 1993)              |
| Species       | Common Name     | Distance | Similarity |
|--------------|-----------------|----------|------------|
| Human        | Homo sapiens    | 0.98     | 0.42       |
| Human        | Homo sapiens    | 0.98     | 0.41       |
| Human        | Homo sapiens    | 0.95     | 0.39       |
| Human        | Homo sapiens    | 0.98     | 0.36       |
| Human        | Homo sapiens    | 0.99     | 0.35       |
| Human        | Homo sapiens    | 0.97     | 0.33       |
| Human        | Homo sapiens    | 0.98     | 0.32       |
| Human        | Homo sapiens    | 0.97     | 0.29       |
| Human        | Homo sapiens    | 0.96     | 0.27       |
| Human        | Homo sapiens    | 0.98     | 0.25       |
| Human        | Homo sapiens    | 0.95     | 0.25       |
| Human        | Homo sapiens    | 0.95     | 0.25       |
| Human        | Homo sapiens    | 0.97     | 0.24       |
| Human        | Homo sapiens    | 0.95     | 0.24       |
| Human        | Homo sapiens    | 0.96     | 0.24       |
| Human        | Homo sapiens    | 0.61     | 0.22       |
| Human        | Homo sapiens    | 0.92     | 0.22       |

*Ogino et al., 1985*
*Ohtani et al., 2004*
*Ohtani and Yamamoto, 2011*
*Ritz et al., 1996*
*Ohtani and Yamamoto, 2010*
*Ohtani et al., 2002*
*Ritz-Timme et al., 2003*
*Ohtani, 1995*
*van den Oetelaar and Hoenders, 1989*
*Ritz et al., 1994*
*Ohtani et al., 2002*
*Rajkumari et al., 2013*
*Ohtani and Yamamoto, 2011*
*Ohtani et al., 2002*
*Helfman and Bada, 1976*
*Shapiro et al., 1991*
*Ritz et al., 1994*
|                |                  |        |        |                                                                 |
|----------------|------------------|--------|--------|-----------------------------------------------------------------|
| Human          | Homo sapiens     | 1.00   | 0.18   | (Ohtani and Yamamoto, 2010)                                      |
| Human          | Homo sapiens     | 0.92   | 0.17   | (Ritz et al., 1990)                                             |
| Human          | Homo sapiens     | 0.87   | 0.14   | (Ohtani et al., 2002)                                           |
| Human          | Homo sapiens     | 0.89   | 0.14   | (Man et al., 1983)                                              |
| Human          | Homo sapiens     | 0.90   | 0.14   | (Verzijl et al., 2000)                                          |
| Human          | Homo sapiens     | 0.94   | 0.14   | (Pfeiffer et al., 1995a)                                        |
| Human          | Homo sapiens     | 0.73   | 0.12   | (Ohtani et al., 1998)                                           |
| Human          | Homo sapiens     | 0.78   | 0.10   | (Ohtani et al., 2002)                                           |
| Human          | Homo sapiens     | 0.83   | 0.09   | (Masters et al., 1977)                                          |
| Human          | Homo sapiens     | 0.81   | 0.09   | (Maroudas et al., 1998)                                         |
| Human          | Homo sapiens     | 0.77   | 0.08   | (Shimoyama and Harada, 1984)                                     |
| Human          | Homo sapiens     | 0.58   | 0.07   | (Ohtani et al., 2002)                                           |
| Human          | Homo sapiens     | 0.61   | 0.06   | (Verzijl et al., 2000)                                          |
| Human          | Homo sapiens     | 0.55   | 0.06   | (Ohtani et al., 2002)                                           |
| Human          | Homo sapiens     | 0.76   | 0.06   | (Fujii et al., 1999)                                            |
| Human          | Homo sapiens     | 0.71   | 0.06   | (Pfeiffer et al., 1995b)                                        |
| Mammal         | Fin whale and Narwhals | 0.90   | 0.39   | (Garde et al., 2007)                                            |
|                | Scientific Name                     | OT | FL | Reference                           |
|----------------|-------------------------------------|----|----|-------------------------------------|
| Harp seal      | Pagophilus groenlandicus           | 0.93 | 0.36 | (Garde et al., 2010)               |
| Eastern bluebird | Sialia sialis                     | 0.45 | 0.98 | (Hunter, 1989)                    |
| Brown pelican  | Pelecanus occidentalis             | 0.53 | 0.17 | (Hunter, 1989)                    |
| Western gull   | Larus occidentalis                 | 0.02 | 0.04 | (Hunter, 1989)                    |
| Five-lined snapper | Lutjanus quinquelineatus         | 0.91 | 75.20 | (Newman et al., 1996)             |
| Brown-striped red snapper | Lutjanus vitta              | 0.80 | 62.09 | (Newman et al., 2000a)            |
| Brown-striped red snapper | Lutjanus vitta              | 0.84 | 53.15 | (Newman et al., 2000a)            |
| Yellow-banded snapper | Lutjanus adetii                | 0.81 | 50.38 | (Newman et al., 1996)             |
| Spanish flag snapper | Lutjanus carponotatus        | 0.68 | 31.61 | (Newman et al., 2000a)            |
| Spanish flag snapper | Lutjanus carponotatus        | 0.68 | 26.67 | (Newman et al., 2000a)            |
| Deepsea jewfish | Glaucosoma buergeri               | 0.91 | 8.01  | (Newman, 2002a)                   |
| Emperor red snapper | Lutjanus sebae                 | 0.88 | 6.40  | (Newman and Dunk, 2002)           |
| Emperor red snapper | Lutjanus sebae                 | 0.85 | 6.29  | (Newman and Dunk, 2002)           |
| Malabar blood snapper | Lutjanus malabaricus        | 0.92 | 6.24  | (Newman, 2002b)                   |
| Emperor red snapper | Lutjanus sebae                 | 0.72 | 0.47  | (Newman et al., 2000b)            |
| Crimson snapper | Lutjanus erythropterus           | 0.49 | 0.41  | (Newman et al., 2000b)            |
| Species                        | Scientific Name             | OL | OH | OB |
|-------------------------------|-----------------------------|----|----|----|
| Malabar blood snapper         | Lutjanus malabaricus       | 0.73 | 0.90 | 0.71 |
| Crimson snapper               | Lutjanus erythropterus     | 0.86 | 0.89 | 0.85 |
| Malabar blood snapper         | Lutjanus malabaricus       | 0.90 | 0.89 | 0.85 |
| Emperor red snapper           | Lutjanus sebae             | 0.89 | 0.89 | 0.87 |
| Five-lined snapper            | Lutjanus quinquelineatus    | 0.53 | 0.53 | 0.54 |
| Yellow-banded snapper         | Lutjanus adetii             | 0.35 | 0.35 | 0.46 |
| Brown-striped red snapper     | Lutjanus vitta              | 0.45 | 0.45 | 0.54 |
| Spanish flag snapper          | Lutjanus carponotatus       | 0.28 | 0.28 | 0.35 |
| Deepsea jewfish               | Glaucosoma buergeri        | 0.84 | 0.84 | 0.85 |
| Malabar blood snapper         | Lutjanus malabaricus       | 0.71 | 0.71 | 0.85 |
| Emperor red snapper           | Lutjanus sebae             | 0.34 | 0.34 | 0.35 |
| Deepsea jewfish               | Glaucosoma buergeri        | 0.91 | 0.91 | 0.91 |
| Malabar blood snapper         | Lutjanus malabaricus       | 0.85 | 0.85 | 0.85 |
| Yellow-banded snapper         | Lutjanus adetii             | 0.46 | 0.46 | 0.46 |
| Brown-striped red snapper     | Lutjanus vitta              | 0.54 | 0.54 | 0.54 |

Notes:
- OL: Otolithometry
- OH: Otolithometry
- OB: Otolithometry
| Fish                          | Otolith ring count | Age-length key |
|------------------------------|-------------------|----------------|
| Five-lined snapper Lutjanus quinquelineatus | 0.56   1.62 | (Newman et al., 1996) |
| Spanish flag snapper Lutjanus carponotatus | 0.32   1.06 | (Newman et al., 2000a) |
| Malabar blood snapper Lutjanus malabaricus | 0.73   0.69 | (Newman, 2002b) |
| Deepsea jewfish Glaucosoma buergeri | 0.77   0.66 | (Newman, 2002a) |
| Emperor red snapper Lutjanus sebae | 0.32   0.51 | (Newman and Dunk, 2002) |
| Emperor red snapper Lutjanus sebae | 0.77   0.32 | (Newman et al., 2000b) |
| Crimson snapper Lutjanus erythropterus | 0.52   0.23 | (Newman et al., 2000b) |
| Malabar blood snapper Lutjanus malabaricus | 0.75   0.19 | (Newman et al., 2000b) |
| Murray cod Maccullochella peeli | 1.00   Inf | (Gooley, 1992) |
| Crimson snapper Lutjanus. erythropterus | 0.95   3.84 | (Cappo et al., 2000) |
| Carpenter seabream Argyrozone argyrozoa | 1.00   3.34 | (Brouwer and Griffiths, 2004) |
| Australasian snapper Pagrus auratus | 0.99   2.46 | (Francis et al., 1992) |
| John's snapper Lutjanus. johnii | 0.89   2.38 | (Cappo et al., 2000) |
| Japanese black porgy Acanthopagrus schlegeli | 0.73   2.27 | (Tsui, 2005) |
| Mangrove red snapper Lutjanus argentimaculatus | 0.86   1.96 | (Tsui, 2005) |
| Emperor red snapper Lutjanus. sebae | 0.60   1.27 | (Cappo et al., 2000) |
| Shortnose greeneeye Chlorophthalmus agassizii Bonaparte | 0.92   12.58 | (D’Onghia et al., 2006) |
| Species                              | Scientific Name                  | Length (m) | Weight (kg) | Reference                                |
|--------------------------------------|----------------------------------|------------|-------------|------------------------------------------|
| Corvina reina                        | Cynoscion albus                  | 0.92       | 8.62        | (Mug-Villanueva et al., 1994)            |
| Myers' icefish                       | Chionodraco myersi               | 0.90       | 7.55        | (Morales-Nin et al., 2000)              |
| Greater amberjack                    | Seriola dumerili                 | 0.79       | 5.48        | (Manooch llii and Potts, 1997)          |
| Vermilion snapper                    | Rhombopiltes aurorubens          | 0.73       | 5.07        | (Potts et al., 1998)                    |
| Red snapper                          | Lutjanus campechanus             | 0.62       | 3.78        | (White and Palmer, 2004)                |
| Myers' icefish                       | Chionodraco myersi               | 0.76       | 2.89        | (Morales-Nin et al., 2000)              |
| Otolites ruber                       | Tigertooth croaker               | 0.86       | 2.73        | (Gh et al., 2012)                       |
| Cadenat's rockfish                   | Scorpaena loppei                 | 0.56       | 1.93        | (Ordines et al., 2012)                  |
| Namibian silver kob                  | Argyrosomus inodorus             | 0.63       | 1.85        | (Kirchner and Voges, 1999)              |
| Sharpsnout seabream                  | Diplodus puntazzo                | 0.84       | 1.34        | (Domínguez-Seoane et al., 2006)         |
| Sand steenbras                       | Lithognathus mormyrus            | 0.53       | 0.97        | (Pajuelo et al., 2002)                  |
| Roughhead grenadier                  | Macrourus berglax                | 0.87       | 0.93        | (Rodríguez-Marín et al., 2002)          |
| Two-banded seabream                  | Diplodus vulgaris                | 0.45       | 0.67        | (Pajuelo and Lorenzo, 2003)             |
| Roughhead grenadier                  | Macrourus berglax                | 0.91       | 0.62        | (Rodríguez-Marín et al., 2002)          |
| Cadenat's rockfish                   | Scorpaena loppei                 | 0.35       | 0.55        | (Ordines et al., 2012)                  |
| West coast steenbras                 | Lithognathus aureti              | 0.87       | 0.36        | (Holtzhausen and Kirchner, 2001)        |
| Antarctic plunderfish                | Dolloidraco longedorsalis        | 0.30       | 0.23        | (Morales-Nin et al., 2000)              |
| Skeletochronology | Mammal          | Animal Species               | β  | σ  | Source                           |
|-------------------|-----------------|------------------------------|----|----|----------------------------------|
|                   | Grey mouse lemur| Microcebus murinus          | 1.00 | 4.80 | (Castanet et al., 2004)         |
| Reptile           | Green sea turtle| Chelonia mydas               | 1.00 | Inf | (Snover et al., 2011)           |
|                   | Nile monitor    | Varanus niloticus            | 1.00 | Inf | (de Buffrénil and Castanet, 2000) |
|                   | Kemp's ridley sea turtles | Lepidochelys kempi | 0.93 | 2.20 | (Snover and Hohn, 2004)         |
|                   | Freshwater crocodile | Crocodylus johnstoni | 0.99 | 1.51 | (Tucker, 1997)                  |
|                   | Arizona Tiger Salamander | Ambystoma tigrinnus nebulosum | 0.74 | 0.29 | (Eden et al., 2007)            |
|                   | Green turtles   | Chelonia mydas               | 0.00 | 0.00 | (Bjorndal et al., 1998)         |
| Amphibian         | European tree frog | Hyla arborea               | 1.00 | Inf | (Friedl and Klump, 1997)        |

4 Note: OW, otolith weight; OL, otolith length; OH, otolith height; OB, otolith breath. Inf, infinite $|\beta/\sigma|$ for $\sigma = 0$, i.e. no error in age determination.
ALLSOPP, R. C., VAZIRI, H., PATERSON, C., GOLDSTEIN, S., YOUNGLAI, E. V., FUTCHER, A. B., GREIDER, C. W. & HARLEY, C. B. 1992. Telomere length predicts replicative capacity of human fibroblasts. *Proceedings of the National Academy of Sciences of the United States of America*, 89, 10114-10118.

ANGELIER, F., VLECK, C. M., HOLBERTON, R. L. & MARRA, P. P. 2013. Telomere length, non-breeding habitat and return rate in male American redstarts. *Functional Ecology*, 27, 342-350.

ARGYLE, D., ELLSMORE, V., GAULT, E. A., MUNRO, A. F. & NASIR, L. 2003. Equine telomeres and telomerase in cellular immortalisation and ageing. *Mechanisms of Ageing and Development*, 124, 759-764.

BEKAERT, B., KAMALANDUA, A., ZAPICO, S. C., VAN DE VOORDE, W. & DECORTE, R. 2015. Improved age determination of blood and teeth samples using a selected set of DNA methylation markers. *Epigenetics*, 10, 922-930.

BIZE, P., CRISCUOLO, F., METCALFE, N. B., NASIR, L. & MONAGHAN, P. 2009. Telomere dynamics rather than age predict life expectancy in the wild. *Proceedings of the Royal Society B-Biological Sciences*, 276, 1679-1683.

BJORNDAL, K. A., BOLTEN, A. B., BENNETT, R. A., JACOBSON, E. R., WRONSKI, T. J., VALESKI, J. J. & ELIAZAR, P. J. 1998. Age and growth in sea turtles: limitations of skeletochronology for demographic studies. *Copeia*, 23-30.

BOCKLANDT, S., LIN, W., SEHL, M. E., SÁNCHEZ, F. J., SINSHEIMER, J. S., HORMUTH, S. & VILAIN, E. 2011. Epigenetic Predictor of Age. *PLoS ONE*, 6, e14821.
BRONIKOWSKI, A. M. 2008. The evolution of aging phenotypes in snakes: A review and synthesis with new data. *Age*, 30, 169-176.

BROUWER, S. L. & GRIFFITHS, M. H. 2004. Age and growth of *Argyrozoa argyrozoa* (Pisces: Sparidae) in a marine protected area: an evaluation of methods based on whole otoliths, sectioned otoliths and mark-recapture. *Fisheries Research*, 67, 1-12.

CAPPO, M., EDEN, P., NEWMAN, S. J. & ROBERTSON, S. 2000. A new approach to validation of periodicity and timing of opaque zone formation in the otoliths of eleven species of *Lutjanus* from the central Great Barrier Reef. *Fishery Bulletin*, 98, 474-488.

CASTANET, J., CROCI, S., AUJARD, F., PERRET, M., CUBO, J. & DE MARGERIE, E. 2004. Lines of arrested growth in bone and age estimation in a small primate: *Microcebus murinus*. *Journal of Zoology*, 263, 31-39.

CHO, S., GE, J., SEO, S. B., KIM, K., LEE, H. Y. & LEE, S. D. 2014. Age estimation via quantification of signal-joint T cell receptor excision circles in Koreans. *Legal Medicine*, 16, 135-138.

CHRISTENSEN, B. C., HOUSEMAN, E. A., MARSIT, C. J., ZHENG, S., WRENSCH, M. R., WIEMELS, J. L., NELSON, H. H., KARAGAS, M. R., PADBURY, J. F., BUENO, R., SUGARBAKER, D. J., YEH, R.-F., WIENCKE, J. K. & KELSEY, K. T. 2009. Aging and Environmental Exposures Alter Tissue-Specific DNA Methylation Dependent upon CpG Island Context. *PLoS Genet*, 5, e1000602.

D’ONGHIA, G., SION, L., MAIORANO, P., MYTILINEOU, C., DALESSANDRO, S., CARLUCCI, R. & DESANTIS, S. 2006. Population biology and life strategies of *Chlorophthalmus agassizii* Bonaparte, 1840 (Pisces: Osteichthyes) in the Mediterranean Sea. *Marine Biology*, 149, 435-446.
DE BUFFRÉNIL, V. & CASTANET, J. 2000. Age estimation by skeletochronology in the Nile monitor (Varanus niloticus), a highly exploited species. *Journal of Herpetology*, 414-424.

DOMÍNGUEZ-SEOANE, R., PAJUELO, J. G., LORENZO, J. M. & RAMOS, A. G. 2006. Age and growth of the sharpsnout seabream *Diplodus puntazzo* (Cetti, 1777) inhabiting the Canarian archipelago, estimated by reading otoliths and by backcalculation. *Fisheries Research*, 81, 142-148.

DOUEK, D. C., MCFARLAND, R. D., KEISER, P. H., GAGE, E. A., MASSEY, J. M., HAYNES, B. F., POLIS, M. A., HAASE, A. T., FEINBERG, M. B., SULLIVAN, J. L., JAMIESON, B. D., ZACK, J. A., PICKER, L. J. & KOUP, R. A. 1998. Changes in thymic function with age and during the treatment of HIV infection. *Nature*, 396, 690-695.

EDEN, C. J., WHITEMAN, H. H., DUOBINIS -GRAY, L. & WISSINGER, S. A. 2007. Accuracy assessment of skeletochronology in the Arizona tiger salamander (Ambystoma tigrinum nebulosum). *Copeia*, 2007, 471-477.

FOOTE, C. G. 2008. *Avian telomere dynamics*. PhD thesis, University of Glasgow.

FRANCIS, R. I. C. C., PAUL, L. J. & MULLIGAN, K. P. 1992. Ageing of adult snapper (*Pagrus auratus*) from otolith annual ring counts: validation by tagging and oxytetracycline injection. *Australian Journal of Marine & Freshwater Research*, 43, 1069-1089.

FRIEDL, T. W. & KLUMP, G. M. 1997. Some aspects of population biology in the European treefrog, Hyla arborea. *Herpetologica*, 321-330.

FU, S. J., FAN, C. C., SONG, H. W. & WEI, F. Q. 1995. Age estimation using a modified HPLC determination of ratio of aspartic acid in dentin. *Forensic Science International*, 73, 35-40.
FUJII, N., TAKEMOTO, L. J., MOMOSE, Y., MATSUMOTO, S., HIROKI, K. & AKABOSHI, M. 1999. Formation of four isomers at the Asp-151 residue of aged human αA-crystallin by natural aging. *Biochemical and Biophysical Research Communications, 265*, 746-751.

FURUGORI, E., HIRAYAMA, R., NAKAMURA, K. I., KAMMORI, M., ESAKI, Y. & TAKUBO, K. 2000. Telomere shortening in gastric carcinoma with aging despite telomerase activation. *Journal of Cancer Research and Clinical Oncology, 126*, 481-485.

GARDE, E., FRIE, A. K., DUNSHEA, G., HANSEN, S. H., KOVACS, K. M. & LYDERSEN, C. 2010. Harp seal ageing techniques-teeth, aspartic acid racemization, and telomere sequence analysis. *Journal of Mammalogy, 91*, 1365-1374.

GARDE, E., HEIDE-JORGENSEN, M. P., HANSEN, S. H., NACHMAN, G. & FORCHHAMMER, M. C. 2007. Age-specific growth and remarkable longevity in narwhals (*Monodon monoceros*) from West Greenland as estimated by aspartic acid racemization. *Journal of Mammalogy, 88*, 49-58.

GH, E., SAVARI, A., KOCHANIAN, P. & MOTLAGH A, T. 2012. Age, growth and length at first maturity of *Otolithes ruber* in the Northwestern part of the Persian Gulf, based on age estimation using otolith. *Iran. J. Fish. Sci, 11*, 13-27.

GOOLEY, G. J. 1992. Validation of the use of otoliths to determine the age and growth of Murray cod, *Maccullochella peeli* (Mitchell) (Percichthyidae), in Lake Charlegrark, western Victoria. *Australian Journal of Marine & Freshwater Research, 43*, 1091-1102.

HALL, M. E., NASIR, L., DAUNT, F., GAULT, E. A., CROXALL, J. P., WANLESS, S. & MONAGHAN, P. 2004. Telomere loss in relation to age and early environment in long-lived birds. *PROCEEDINGS OF THE ROYAL SOCIETY B-BIOLOGICAL SCIENCES, 271*, 1571-1576.
HANNUM, G., GUINNEY, J., ZHAO, L., ZHANG, L., HUGHES, G., SADDA, S., KLOTZLE, B., BIBIKOVA, M., FAN, J.-B., GAO, Y., DECONDE, R., CHEN, M., RAJAPAKSE, I., FRIEND, S., IDEKER, T. & ZHANG, K. 2013. Genome-wide Methylation Profiles Reveal Quantitative Views of Human Aging Rates. Molecular Cell, 49, 359-367.

HASTIE, N. D., DEMPSTER, M., DUNLOP, M. G., THOMPSON, A. M., GREEN, D. K. & ALLSHIRE, R. C. 1990. Telomere reduction in human colorectal carcinoma and with ageing. Nature, 346, 866-868.

HATAKEYAMA, H., NAKAMURA, K. I., IZUMIYAMA-SHIMOMURA, N., ISHII, A., TSUCHIDA, S., TAKUBO, K. & ISHIKAWA, N. 2008. The teleost Oryzias latipes shows telomere shortening with age despite considerable telomerase activity throughout life. Mechanisms of Ageing and Development, 129, 550-557.

HATASE, H., SUDO, R., WATANABE, K. K., KASUGAI, T., SAITO, T., OKAMOTO, H., UCHIDA, I. & TSUKAMOTO, K. 2008. Shorter telomere length with age in the loggerhead turtle: A new hope for live sea turtle age estimation. Genes and Genetic Systems, 83, 423-426.

HAUSSMANN, M. F. & MAUCK, R. A. 2008. New strategies for telomere-based age estimation. Molecular Ecology Resources, 264–274.

HAUSSMANN, M. F. & VLECK, C. M. 2002. Telomere length provides a new technique for aging animals. Oecologia, 325-328.

HAUSSMANN, M. F., VLECK, C. M. & NISBET, I. C. T. 2003a. Calibrating the telomere clock in common terns, Sterna hirundo. Experimental Gerontology, 38, 787-789.

HAUSSMANN, M. F., WINKLER, D. W., O’REILLY, K. M., HUNTINGTON, C. E., NISBET, I. C. T. & VLECK, C. M. 2003b. Telomeres shorten more slowly in long-lived birds and mammals than in short-lived ones. Proceedings of the Royal Society B-Biological Sciences, 270, 1387-1392.
HELFFMAN, P. M. & BADA, J. L. 1976. Aspartic acid racemisation in dentine as a measure of ageing. *Nature*, 262, 279-281.

HOLTZHAUSEN, J. A. & KIRCHNER, C. H. 2001. Age and growth of two populations of West Coast steenbras *Lithognathus auri* in Namibian waters, based on otolith readings and mark-recapture data. *South African Journal of Marine Science*, 169-179.

HORN, T., GEMMELL, N. J., ROBERTSON, B. C. & BRIDGES, C. R. 2008. Telomere length change in European sea bass (*Dicentrarchus labrax*). *Australian Journal of Zoology*, 56, 207-210.

HORN, T., ROBERTSON, B. C., WILL, M., EASON, D. K., ELLIOTT, G. P. & GEMMELL, N. J. 2011. Inheritance of telomere length in a bird. *PLoS ONE*, 6, e17199.

HORVATH, S. 2013. DNA methylation age of human tissues and cell types. *Genome biology*, 14, R115.

HORVATH, S., ERHART, W., BROSCH, M., AMMERPOHL, O., VON SCHÖNFELS, W., AHRENS, M., HEITS, N., BELL, J. T., TSAI, P.-C. & SPECTOR, T. D. 2014. Obesity accelerates epigenetic aging of human liver. *Proceedings of the National Academy of Sciences*, 111, 15538-15543.

HUNTER, S. A. 1989. *Aspartic acid racemization in tendons as an indication of age in three avian species*. PhD thesis, Southern Illinois University at Carbondale.

ITO, G., YOSHIMURA, K. & MOMOI, Y. 2015. Gene analysis of signal-joint T cell receptor excision circles and their relationship to age in dogs. *Veterinary Immunology and Immunopathology*, 166, 1-7.

IZZO, C. 2010. *Patterns of telomere length change with age in aquatic vertebrates and the phylogenetic distribution of the pattern among jawed vertebrates*. PhD thesis, University of Adelaide.
JUOLA, F. A., HAUSSMANN, M. F., DEARBORN, D. C. & VLECK, C. M. 2006. Telomere shortening in a long-lived marine bird: cross-sectional analysis and test of an aging tool. Auk, 123, 775-783.

KANG, M. K., SWEE, J., KIM, R. H., BALUDA, M. A. & PARK, N.-H. 2002. The telomeric length and heterogeneity decrease with age in normal human oral keratinocytes. Mechanisms of Ageing and Development, 123, 585-592.

KATEPALLI, M. P., ADAMS, A. A., LEAR, T. L. & HOROHOV, D. W. 2008. The effect of age and telomere length on immune function in the horse. Developmental & Comparative Immunology, 32, 1409-1415.

KIRCHNER, C. H. & VOGES, S. F. 1999. Growth of Namibian silver kob Argyrosomus inodorus based on otoliths and mark-recapture data. South African Journal of Marine Science, 201-209.

KOCH, C. M. & WAGNER, W. 2011. Epigenetic-aging-signature to determine age in different tissues. Aging (Albany NY), 3, 1018.

LAHNERT, P. 2005. An improved method for determining telomere length and its use in assessing age in blood and saliva. Gerontology, 51, 352-356.

LEE, H. Y., JUNG, S.-E., OH, Y. N., CHOI, A., YANG, W. I. & SHIN, K.-J. 2015. Epigenetic age signatures in the forensically relevant body fluid of semen: a preliminary study. Forensic science international. Genetics, 19, 28-34.

LEE, W. W., NAM, K. H., TERAO, K. & YOSHIKAWA, Y. 2002. Age-related telomere length dynamics in peripheral blood mononuclear cells of healthy cynomolgus monkeys measured by Flow FISH. Immunology, 105, 458-465.

LINDSEY, J., MCGILL, N. I., LINDSEY, L. A., GREEN, D. K. & COOKE, H. J. 1991. In vivo loss of telomeric repeats with age in humans. Mutation Research, 256, 45-48.
MAEGAWA, S., HINKAL, G., KIM, H. S., SHEN, L., ZHANG, L., ZHANG, J., ZHANG, N., LIANG, S.,
DONEHOWER, L. A. & ISSA, J.-P. J. 2010. Widespread and tissue specific age-related
DNA methylation changes in mice. Genome research, 20, 332-340.

MAN, E. H., SANDHOUSE, M. E., BURG, J. & FISHER, G. H. 1983. Accumulation of D-aspartic
acid with age in the human brain. Science, 220, 1407-8.

MANOOCH III, C. S. & POTTS, J. C. 1997. Age, growth and mortality of greater amberjack
from the southeastern United States. Fisheries Research, 30, 229-240.

MAROUDAS, A., BAYLISS, M. T., UCHITEL-KAUSHANSKY, N., SCHNEIDERMAN, R. & GILAV, E.
1998. Aggrecan turnover in human articular cartilage: use of aspartic acid
racemization as a marker of molecular age. Archives of Biochemistry and Biophysics,
350, 61-71.

MASTERS, P. M., BADA, J. L. & ZIGLER, J. S. 1977. Aspartic-acid racemization in human lens
during aging and in cataract formation. Nature, 268, 71-73.

MELK, A., RAMASSAR, V., HELMS, L. M. H., MOORE, R., RAYNER, D., SOLEZ, K. & HALLORAN,
P. F. 2000. Telomere shortening in kidneys with age. Journal of the American Society
of Nephrology, 11, 444-453.

MIYASHITA, N., SHIGA, K., YONAI, M., KANEYAMA, K., KOBAYASHI, S., KOJIMA, T., GOTO, Y.,
KISHI, M., ASO, H., SUZUKI, T., SAKAGUCHI, M. & NAGAI, T. 2002. Remarkable
differences in telomere lengths among cloned cattle derived from different cell
types. Biology of Reproduction, 66, 1649-1655.

MORALES-NIN, B., MORANTA, J. & BALGUERIAS, E. 2000. Growth and age validation in high-
Antarctic fish. Polar Biology, 23, 626-634.

MUG-VILLANUEVA, M., GALLUCCI, V. F. & LAI, H.-L. 1994. Age determination of corvina reina
(Cynoscion albus) in the Gulf of Nicoya, Costa Rica, based on examination and
analysis of hyaline zones, morphology and microstructure of otoliths. *Journal of Fish Biology*, 45, 177-191.

NASIR, L., DEVLIN, P., MCKEVITT, T., RUTTEMAN, G. & ARGYLE, D. J. 2001. Telomere lengths and telomerase activity in dog tissues: A potential model system to study human telomere and telomerase biology. *Neoplasia*, 3, 351-359.

NEWMAN, S. J. 2002a. Age, growth, mortality and population characteristics of the pearl perch, *Glaucosoma buergeri* Richardson 1845, from deeper continental shelf waters off the Pilbara coast of north-western Australia. *Journal of Applied Ichthyology*, 18, 95-101.

NEWMAN, S. J. 2002b. Growth rate, age determination, natural mortality and production potential of the scarlet seaperch, *Lutjanus malabaricus* Schneider 1801, off the Pilbara coast of north-western Australia. *Fisheries Research*, 58, 215-225.

NEWMAN, S. J., CAPPO, M. & WILLIAMS, D. M. 2000a. Age, growth and mortality of the stripey, *Lutjanus carponotatus* (Richardson) and the brown-stripe snapper, *L. vitta* (Quoy and Gaimard) from the central Great Barrier Reef, Australia. *Fisheries Research*, 48, 263-275.

NEWMAN, S. J., CAPPO, M. & WILLIAMS, D. M. 2000b. Age, growth, mortality rates and corresponding yield estimates using otoliths of the tropical red snappers, *Lutjanus erythropterus*, *L. malabaricus* and *L. sebae*, from the central Great Barrier Reef. *Fisheries Research*, 48, 1-14.

NEWMAN, S. J. & DUNK, I. J. 2002. Growth, age validation, mortality, and other population characteristics of the red emperor snapper, *Lutjanus sebae* (Cuvier, 1828), off the Kimberley coast of north-western Australia. *ESTUARINE COASTAL AND SHELF SCIENCE*, 55, 67-80.
NEWMAN, S. J., WILLIAMS, D. M. & RUSS, G. R. 1996. Age validation, growth and mortality rates of the tropical snappers (Pisces: Lutjanidae) *Lutjanus adetii* (Castelnau, 1873) and *L. quinquelineatus* (Bloch, 1790) from the central Great Barrier Reef, Australia. *Marine and Freshwater Research*, 47, 575-584.

OGINO, T., OGINO, H. & NAGY, B. 1985. Application of aspartic acid racemization to forensic odontology: Post mortem designation of age at death. *Forensic Science International*, 29, 259-267.

OHTANI, S. 1994. Age estimation by aspartic acid racemization in dentin of deciduous teeth. *Forensic Science International*, 68, 77-82.

OHTANI, S. 1995. Studies on age estimation using racemization of aspartic acid in cementum. *Journal of Forensic Sciences*, 40, 805-7.

OHTANI, S., MATSUSHIMA, Y., KABAYASHI, Y. & KISHI, K. 1998. Evaluation of aspartic acid racemization ratios in the human femur for age estimation. *Journal of forensic sciences*, 43, 949-953.

OHTANI, S., MATSUSHIMA, Y., KOBAYASHI, Y. & YAMAMOTO, T. 2002. Age estimation by measuring the racemization of aspartic acid from total amino acid content of several types of bone and rib cartilage: A preliminary account. *Journal of Forensic Sciences*, 47, 32-36.

OHTANI, S., SUGIMOTO, H., SUGENO, H., YAMAMOTO, S. & YAMAMOTO, K. 1995. Racemization of aspartic-acid in human cementum with age. *Archives of Oral Biology*, 40, 91-95.

OHTANI, S., YAMADA, Y., YAMAMOTO, T., ARANY, S., GONMORI, K. & YOSHIOKA, N. 2004. Comparison of age estimated from degree of racemization of aspartic acid, glutamic acid and alanine in the femur. *Journal of Forensic Sciences*, 49, 441-445.
OHTANI, S. & YAMAMOTO, K. 1987. Age estimation using the racemization of aspartic acid on human dentin. *Nihon Hoigaku Zasshi*, 41, 181-90.

OHTANI, S. & YAMAMOTO, K. 1991. Age estimation using the racemization of amino acid in human dentin. *Journal of Forensic Sciences*, 36, 792-800.

OHTANI, S. & YAMAMOTO, K. 1992. Estimation of age from a tooth by means of racemization of an amino acid, especially aspartic acid--comparison of enamel and dentin. *Journal of Forensic Sciences*, 37, 1061-7.

OHTANI, S. & YAMAMOTO, T. 2010. Age estimation by amino acid racemization in human teeth. *Journal of Forensic Sciences*, 55, 1630-1633.

OHTANI, S. & YAMAMOTO, T. 2011. Comparison of age estimation in Japanese and Scandinavian teeth using amino acid racemization. *Journal of Forensic Sciences*, 56, 244-247.

OLSSON, M., PAULINY, A., WAPSTRA, E., ULLER, T., SCHWARTZ, T. & BLOMQVIST, D. 2011. Sex differences in sand lizard telomere inheritance: Paternal epigenetic effects increases telomere heritability and offspring survival. *PLoS ONE*, 6, e17473.

ORDINES, F., VALLS, M. & GOURAGUINE, A. 2012. Biology, feeding, and habitat preferences of Cadenat's rockfish, *Scorpaena loppei* (Actinopterygii: Scorpaeniformes: Scorpaenidae), in the Balearic Islands (western mediterranean). *Acta Ichthyologica et Piscatoria*, 42, 21-30.

OU, X.-L., GAO, J., WANG, H., WANG, H.-S., LU, H.-L. & SUN, H.-Y. 2012. Predicting Human Age with Bloodstains by sjTREC Quantification. *Plos One*, 7, e42412.

OU, X., ZHAO, H., SUN, H., YANG, Z., XIE, B., SHI, Y. & WU, X. 2011. Detection and quantification of the age-related sjTREC decline in human peripheral blood. *International Journal of Legal Medicine*, 125, 603-608.
PAJUELO, J. G. & LORENZO, J. M. 2003. The growth of the common two-banded seabream, *Diplodus vulgaris* (Teleostei, Sparidae), in Canarian waters, estimated by reading otoliths and by back-calculation. *Journal of Applied Ichthyology*, 19, 79-83.

PAJUELO, J. G., LORENZO, J. M., MÉNDEZ, M., COCA, J. & RAMOS, A. G. 2002. Determination of age and growth of the striped seabream *Lithognathus mormyrus* (Sparidae) in the Canarian archipelago by otolith readings and backcalculation. *Scientia Marina*, 66, 27-32.

PAULINY, A., WAGNER, R. H., AUGUSTIN, J., SZÉP, T. & BLOMQVIST, D. 2006. Age-independent telomere length predicts fitness in two bird species. *Molecular Ecology*, 15, 1681-1687.

PFEIFFER, H., MÖRNSTAD, H. & TEIVENS, A. 1995a. Estimation of chronologic age using the aspartic acid racemization method. I. On human rib cartilage. *International Journal of Legal Medicine*, 108, 19-23.

PFEIFFER, H., MÖRNSTAD, H. & TEIVENS, A. 1995b. Estimation of chronologic age using the aspartic acid racemization method. II. On human cortical bone. *International Journal of Legal Medicine*, 108, 24-26.

POLANOWSKI, A. M., ROBBINS, J., CHANDLER, D. & JARMAN, S. N. 2014. Epigenetic estimation of age in humpback whales. *Molecular Ecology Resources*, 14, 976-987.

POTTS, J. C., MANOOCH III, C. S. & VAUGHAN, D. S. 1998. Age and growth of vermillion snapper from the Southeastern United States. *Transactions of the American Fisheries Society*, 127, 787-795.

QU, D.-Y., DENG, S.-J., GE, Y.-Y., CHEN, S. & OU, X.-L. 2013. Age estimation using content of sjTREC in human peripheral blood. *Fa yi xue za zhi*, 29, 256-272.
RAJKUMARI, S., NIRMAL, M., SUNIL, P. M. & SMITH, A. A. 2013. Estimation of age using aspartic acid racemisation in human dentin in Indian population. *Forensic Science International*, 228, 38-41.

RITZ-TIMME, S., LAUMEIER, I. & COLLINS, M. 2003. Age estimation based on aspartic acid racemization in elastin from the yellow ligaments. *International Journal of Legal Medicine*, 117, 96-101.

RITZ, S., SCHÜTZ, H. W. & PEPPER, C. 1993. Postmortem estimation of age at death based on aspartic acid racemization in dentin: Its applicability for root dentin. *International Journal of Legal Medicine*, 105, 289-293.

RITZ, S., SCHÜTZ, H. W. & SCHWARZER, B. 1990. The extent of aspartic acid racemization in dentin: a possible method for a more accurate determination of age at death? *Zeitschrift für Rechtsmedizin*, 103, 457-462.

RITZ, S., TURZYNSKI, A. & SCHÜTZ, H. W. 1994. Estimation of age at death based on aspartic acid racemization in noncollagenous bone proteins. *Forensic Science International*, 69, 149-159.

RITZ, S., TURZYNSKI, A., SCHÜTZ, H. W., HOLLMANN, A. & ROCHHOLZ, G. 1996. Identification of osteocalcin as a permanent aging constituent of the bone matrix: basis for an accurate age at death determination. *Forensic Science International*, 77, 13-26.

RODRÍGUEZ-MARÍN, E., RUIZ, M. & SARASUA, A. 2002. Validation of roughhead grenadier (*Macrourus berglax*) otolith reading. *Journal of Applied Ichthyology*, 18, 70-80.

SHAPIRO, S. D., ENDICOTT, S. K., PROVINC, M. A., PIERCE, J. A. & CAMPBELL, E. J. 1991. Marked longevity of human lung parenchymal elastic fibers deduced from prevalence of D-aspartate and nuclear weapons-related radiocarbon. *Journal of Clinical Investigation*, 87, 1828-34.
SHIELS, P. G., KIND, A. J., CAMPBELL, K. H. S., WADDINGTON, D., WILMUT, I., COLMAN, A. & SCHNIEKE, A. E. 1999. Analysis of telomere lengths in cloned sheep. *Nature*, 399, 312-317.

SHIMOYAMA, A. & HARADA, K. 1984. An age-determination of an ancient burial mound man by apparent racemization reaction of aspartic-acid in tooth dentin. *Chemistry Letters*, 1661-1664.

SNOVER, M. L. & HOHN, A. A. 2004. Validation and interpretation of annual skeletal marks in loggerhead (Caretta caretta) and Kemp’s ridley (Lepidochelys kempii) sea turtles. *Fishery Bulletin*, 102, 682-692.

SNOVER, M. L., HOHN, A. A., GOSHE, L. R. & BALAZS, G. H. 2011. Validation of annual skeletal marks in green sea turtles Chelonia mydas using tetracycline labeling. *Aquatic Biology*, 12, 197-204.

TAKASAKI, T., TSUJI, A., IKEDA, N. & OHISHI, M. 2003. Age estimation in dental pulp DNA based on human telomere shortening. *International Journal of Legal Medicine*, 117, 232-234.

TSUJI, J. C. Y. 2005. *Evaluation of telomere length as an age-marker in marine teleosts*. MSc thesis, The University of Hong Kong.

TSUJI, A., ISHIKO, A., TAKASAKI, T. & IKEDA, N. 2002. Estimating age of humans based on telomere shortening. *Forensic Science International*, 126, 197-199.

TUCKER, A. D. 1997. Validation of skeletochronology to determine age of freshwater crocodiles (Crocodylus johnstoni). *Marine and Freshwater Research*, 48, 343-351.

UJVARI, B. & MADSEN, T. 2009. Short telomeres in hatchling snakes: erythrocyte telomere dynamics and longevity in tropical pythons. *PloS One*, 4, e7493.
UNRYN, B. M., COOK, L. S. & RIABOWOL, K. T. 2005. Paternal age is positively linked to telomere length of children. *Aging Cell*, 4, 97-101.

VAN DEN OETELAAR, P. J. & HOENDERS, H. J. 1989. Racemization of aspartyl residues in proteins from normal and cataractous human lenses: an aging process without involvement in cataract formation. *Experimental Eye Research*, 48, 209-14.

VERZIJL, N., DEGROOT, J., THORPE, S. R., BANK, R. A., SHAW, J. N., LYONS, T. J., BIJLSMA, J. W. J., LAFEBER, F. P. J. G., BAYNES, J. W. & TEKOPPELE, J. M. 2000. Effect of collagen turnover on the accumulation of advanced glycation end products. *Journal of Biological Chemistry*, 275, 39027-39031.

WEIDNER, C. I., LIN, Q., KOCH, C. M., EISELE, L., BEIER, F., ZIEGLER, P., BAUERSCHLAG, D. O., JÖCKEL, K.-H., ERBEL, R. & MÜHLEISEN, T. W. 2014. Aging of blood can be tracked by DNA methylation changes at just three CpG sites. *Genome biology*, 15, R24.

WHITE, D. B. & PALMER, S. M. 2004. Age, growth, and reproduction of the red snapper, *Lutjanus campechanus*, from the atlantic waters of the southeastern U.S. *Bulletin of Marine Science*, 75, 335-360.

WIEMANN, S. U., SATYANARAYANA, A., TSAHURIDU, M., TILLMANN, H. L., ZENDER, L., KLEMPNAUER, J., FLEMMING, P., FRANCO, S., BLASCO, M. A., MANNS, M. P. & RUDOLPH, K. L. 2002. Hepatocyte telomere shortening and senescence are general markers of human liver cirrhosis. *FASEB JOURNAL*, 16, 935-942.

YANG, L., SUWA, T., WRIGHT, W. E., SHAY, J. W. & HORNBY, P. J. 2001. Telomere shortening and decline in replicative potential as a function of donor age in human adrenocortical cells. *Mechanisms of Ageing and Development*, 122, 1685-1694.

YAZAWA, M., OKUDA, M., SETOGUCHI, A., IWABUCHI, S., NISHIMURA, R., SASAKI, N., MASUDA, K., OHNO, K. & TSUJIMOTO, H. 2001. Telomere length and telomerase
activity in canine mammary gland tumors. *American Journal of Veterinary Research*, 62, 1539-1543.

YOUNG, R. C., KITAYSKY, A. S., HAUSSMANN, M. F., DESCAMPS, S., ORBEN, R. A., ELLIOTT, K. H. & GASTON, A. J. 2013. Age, sex, and telomere dynamics in a long-lived seabird with male-biased parental care. *PLoS ONE*, 8, e74931.

ZBIEC-PIEKARSKA, R., SPOLNICKA, M., KUPIEC, T., MAKOWSKA, Z., SPAS, A., PARYS-PROSZEK, A., KUCHARCZYK, K., PLOSKI, R. & BRANICKI, W. 2015. Examination of DNA methylation status of the ELOVL2 marker may be useful for human age prediction in forensic science. *Forensic Science International-Genetics*, 14, 161-167.

ZUBAKOV, D., LIU, F., VAN ZELM, M., VERMEULEN, J., OOSTRA, B., VAN DUIJN, C., DRIESSEN, G., VAN DONGEN, J., KAYSER, M. & LANGERAK, A. 2010. Estimating human age from T-cell DNA rearrangements. *Current Biology*, 20, R970-R971.