Journal of Applied Ichthyology

J. Appl. Ichthyol. 29 (2013), 801–807

ISSN 0175–8659

Received: June 25, 2012
Accepted: January 8, 2013
doi: 10.1111/jai.12185

Age-based demographics of the pearl perch *Glaucosoma scapulare* (Ramsay, 1881)

By J. Stewart[1,2], W. Sumpton[3], M. Lockett[4] and J. M. Hughes[1,2]

[1]*Cronulla Fisheries Research Centre of Excellence, Cronulla, NSW, Australia;* [2]*Fisheries NSW, Sydney Institute of Marine Science, Mosman, NSW, Australia;* [3]*Queensland Department of Agriculture, Fisheries and Forestry, Ecosciences Precinct, Brisbane, Queensland, Australia;* [4]*Australian Museum, Sydney, New South Wales, Australia*

Summary

This research represents the first age-based demographic assessment of pearl perch, *Glaucosoma scapulare* (Ramsay, 1881), a highly valued species endemic to coastal waters off central eastern Australia. The study was conducted across the species' distribution that encompasses two state jurisdictions (Queensland in the north and New South Wales in the south) using data collected approximately 10 years apart in each state. Estimates of age were made by counting annuli (validated using marginal increment ratios) in sectioned sagittal otoliths. The maximum estimated age was 19 years. Pearl perch attained approx. 12 cm fork length (FL) after one year, 21 cm FL after 2 years and 29 cm FL after 3 years. Fish from the southern end of the species' distribution grew significantly more slowly than those from the northern part of its range. Commercial landings in the north were characterized by greater proportions of larger (>40 cm FL) and older (>6 years) fish than those in the south, with landings mainly of fish between 3 and 6 years of age. The observed variations in age-based demographics of pearl perch highlight the need for a better understanding of patterns of movement and reproduction in developing a model of population dynamics and life-history for this important species. There is a clear need for further, concurrent, age-based studies on pearl perch in the northern and southern parts of its distribution to support the conclusions of the present study based on data collected a decade apart.

Introduction

The pearl perch, *Glaucosoma scapulare* (Ramsay, 1881), is a relatively common demersal fish endemic to the central east coast of Australia. The species is a member of the Glaucosomatidae, a small monogeneric family comprising four species, *G. scapulare*, *G. hebraicum* (Richardson, 1845), *G. buergeri* (Richardson, 1845) and *G. magnificum* (Ogilby, 1915) of perch-like marine fishes occurring over the continental shelf throughout the Indo–Pacific (McKay, 1997). Members of this family, including pearl perch, generally form small schools around submerged reefs, pinnacles and rough rocky bottoms in moderately deep water (up to 150 m), but may also move into shallow coastal waters throughout the day (McKay, 1997). Compared to other glaucosomatids, pearl perch have a limited distribution from Rockhampton in Queensland (23°20′ S) south to Port Jackson in New South Wales (NSW) (33°50′ S), but rarely occur south of Coffs Harbour (30°18′S) (Hutchins and Swainston, 1986; McKay, 1997). Due to this limited distribution and influence of the prevailing southerly flowing Eastern Australian Current in this area (Ridgway and Dunn, 2003), pearl perch are considered to be a single biological stock (Rowling et al., 2010; Department of Employment and Economic Development and Innovation, 2011).

Apart from a taxonomic and distributional review of the family Glaucosomatidae (McKay, 1997) and reported maximum sizes of 70 cm and 7.3 kg (Hutchins and Swainston, 1986), there is no published information on the biology or life-history of pearl perch. Studies on the congeneric species *G. hebraicum* (western Australian dhufish) and *G. buergeri* (northern pearl perch) report them to be slow growing, long-lived (26 to 39 years) species that are vulnerable to overfishing (Hesp et al., 2002; Newman, 2002). All glaucosomatids are reported to be excellent table fish (Hutchins and Swainston, 1986; Hesp et al., 2002; Newman, 2002) and are important targets of commercial and recreational fishers throughout their ranges.

Although the species distributional range is relatively small, the stock straddles jurisdictional areas of the state fisheries agencies of NSW and Queensland. Each state jurisdiction has similar management arrangements for pearl perch, including a recreational daily bag limit of five fish per person. In Queensland a minimum legal length (MLL) of 30 cm total length (TL) was introduced in 1993, and increased to 35 cm TL in 2002. In NSW a MLL was first introduced for pearl perch in 2007 and set at 30 cm TL. Queensland pearl perch is the second most frequently landed species in the southern rocky reef (line) fishery after snapper, *Pagrus auratus* (Bloch and Schneider, 1801), while in NSW it is an important secondary species in the ocean trap and line fishery (New South Wales Department of Primary Industries, 2006; Department of Employment and Economic Development and Innovation, 2011). There are increasing concerns over the long-term sustainability of the fisheries for pearl perch, with increased landings as fishing pressure increases and shifts to grounds traditionally subjected to low levels of fishing (Andersen, 2006). These concerns are exacerbated by the knowledge that other glaucatosomatids exhibit life histories that make them vulnerable to overfishing (Hesp et al., 2002; Newman, 2002).

Understanding age-related dynamics of fish populations provides insight into their life histories and population structures (Campana and Thorrold, 2001; Marriott et al., 2010). The aim of the present study was therefore to utilize historical, unpublished data from the northern end of pearl perch distribution along with more recent data collected from the southern distributional end, to describe for the first time some age-based population demographics and reproductive seasonality. Age-based parameters investigated were growth rates, longevity and age structures in landings.

Materials and methods

Sampling for size composition and biological data

Fishery dependent sampling. The lengths of fish in representative samples of commercial catches of pearl perch were measured in Queensland and NSW approximately a decade apart. Sampling in Queensland was between March 1994 and March 1996, whereas sampling in NSW was between January 2005 and October 2006. All fish in each catch were measured for fork length (FL). A random sample of 20 fish per month was taken for biological assessment (including gonads and otoliths), when available. In Queensland, samples of pearl perch were obtained regularly from commercial line fishers operating along the southern coast of Queensland (24°S – 28°S), whereas the majority of fish sampled in NSW were from commercial catches in Coffs Harbour (~ 30°S).

Extra biological sampling. In addition to samples obtained from the routine monitoring of commercial fishery landings, a further 164 pearl perch were sampled for biological assessment between August 1992 and March 1996 from the Queensland line fishery. Most (150) of these additional samples were <28.7 cm FL (equivalent to the MLL at the time of 30 cm TL) and were used only to investigate maturation and, where otoliths were removed, to model growth. Similarly in NSW, 14 small pearl perch between 9 and 13 cm FL were obtained from the Coffs Harbour commercial prawn trawl fleet during January and February 2006 for age estimation to be used in modelling growth.

Research trawl sampling. Information on the lengths of small pearl perch retained in trawl nets was used to support estimates of early growth rates from size-at-age data. Length frequency distributions of pearl perch, pooled by calendar year quarter, were obtained from catch data of the fisheries research vessel *Kapala* when undertaking exploratory prawn trawl surveys in northern NSW. These trawl surveys were done each calendar year quarter during 1990, 1991, 1992, 1995 and 1996 in depths of 30–45 m.

Estimation of age

Ages of pearl perch were estimated using sagittal otoliths sectioned transversely through the primordium. A total of 520 fish were aged using sectioned otoliths, 286 fish from Queensland (211 from the fishery-dependent sampling 1994–1996 and 75 from the extra biological sampling 1992–1996) and 234 fish from NSW (220 from the fishery-dependent sampling 2005 and 2006 and 14 from the extra biological sampling during 2006). Otoliths were mounted in clear epoxy resin and a single 300–400 μm section cut through their centres using a low speed diamond saw (Buehler isomet). Sections were polished on fine grade lapping film and cleaned before being mounted onto glass slides using Safety Mount or polyester resin. A section was examined under reflected light using a dissecting microscope attached to a video camera, and the image analysed using the Image Pro Plus computer imaging package. The numbers of opaque zones (annuli) were then counted to provide an estimate of age.

The 520 otoliths were aged by one reader with no knowledge of the sampling information associated with each otolith. Sixty-two otoliths from the NSW samples (>25%) were read by a second reader to gain an estimate of the repeatability of readings.

To validate that the opaque zones were formed annually we analysed the marginal increment ratios of the otoliths throughout the year. The marginal increment ratio of each otolith was defined as the distance between the outer edge of the outermost complete opaque zone and the edge of the otolith as a proportion of the distance between the outer edges of the two outer-most opaque zones.

Validation of the first opaque zone was done by counting daily increments in the otoliths of three small (9–12 cm FL) fish that were assumed to be approx. 12 months old, based on the modal progression of small trawl-caught pearl perch. Otoliths from these fish were sectioned and polished to a thickness of about 100 μm and the daily increments were counted along the dorsal margin of the sulcus. Corroborating evidence for our identification of the first opaque zone was gained using the modal progression of small pearl perch that were captured in prawn trawl nets. The mean size of the cohort estimated at 1 year of age was also compared to the estimated size at age 1 from the von Bertalanffy growth function (VBGF).

Growth rates

Growth was estimated by fitting the size-at-age data to the VBGF: $L_t = L_\infty[1 - e^{-k(t-t_0)}]$

Where L_t is the length at age t, L_∞ is the asymptotic length, k is the rate at which the curve approaches the L_∞, and t_0 is the theoretical age of the fish at zero length. For all growth modelling the curve was constrained such that at age 0 the FL was 0.2 cm, the estimated length at larval metamorphosis of the congeneric *Glaucosoma hebraicum* (Pironet and Neira, 1998).

Sex was not determined for samples collected from the Queensland commercial landings, thus growth rates between sexes were compared using only NSW samples. The growth curves for male and female fish from NSW, fitted across equal age ranges, were compared using the analysis of residual sums of squares (ARSS) method (Chen et al., 1992). Spatial variation in growth rate was then examined by comparing growth curves, fitted across equal age ranges, from Queensland and NSW using the same analysis. Data from Queensland and NSW were then combined to calculate growth rate parameters for the population as a whole.

Reproductive activity

The level of reproductive activity was estimated using the gonadosomatic index (GSI) following the method of Cayré and Laloë (1986):

$$GSI = \frac{gonadweight(g)}{FL^3}$$

This method was used instead of utilising fish weight since it was not always possible to determine the weight of fish from which biological material was obtained. Ovaries were collected and the GSI determined from 145 female pearl perch from fishery-dependent sampling in Queensland from 1994 – 1996 and from 72 females from fishery-dependent sampling in NSW waters. Plots of the mean GSI in each state per month were used to describe changes in gonad sizes through time.

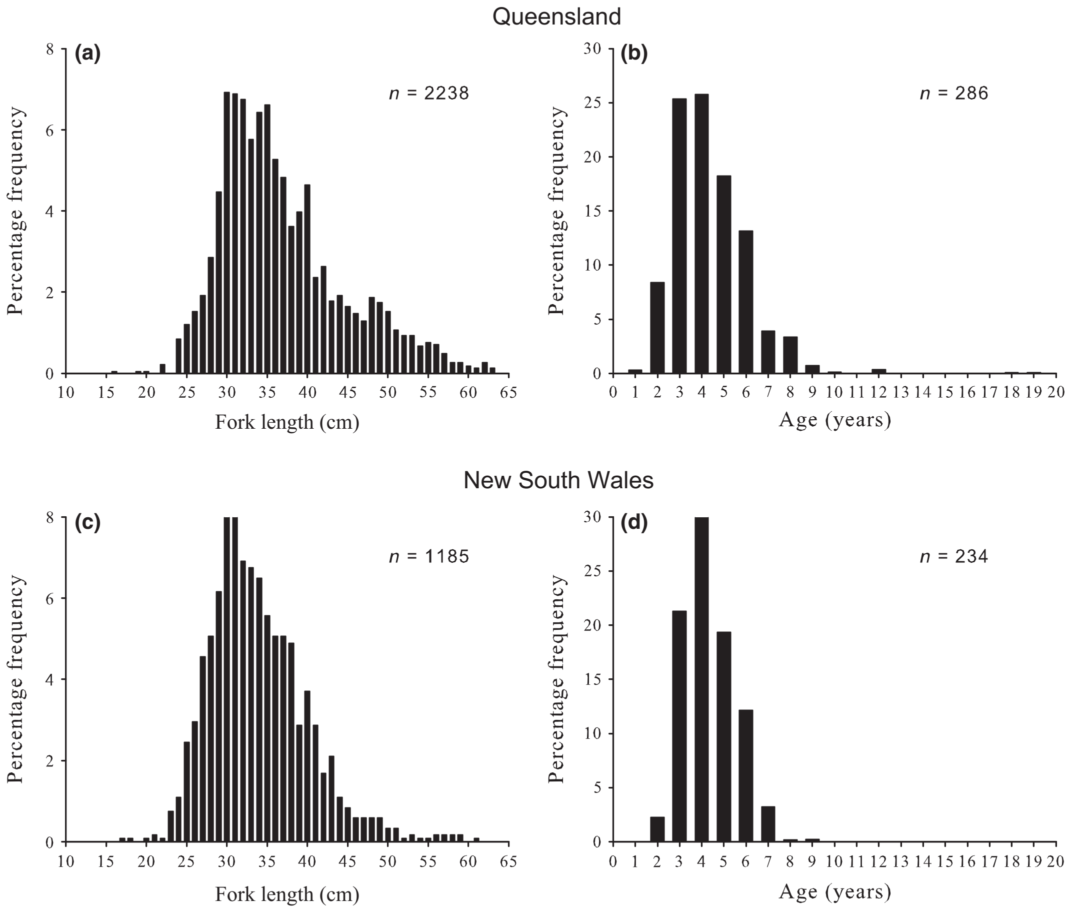

Fig. 1. Lengths and ages of pearl perch, *Glaucosoma scapulare*, in commercial landings, Queensland, 1994/95 (a and b) and New South Wales, 2005/06 (c and d)

Age composition of the landed catch

To examine the age composition of the landed catch in each state we used age length keys (Kimura, 1977; Lai, 1993) constructed using the ages determined from the fishery-dependent sampling during the present study. Age compositions were estimated using these age length keys and the size composition data from each state's commercial fisheries.

Results

Size composition in the landed catches

Lengths of pearl perch in the commercial line fisheries of NSW and Queensland were generally between 25 and 60 cm FL, with the most abundant size class being 30 cm FL in both states (Fig. 1). There was a greater percentage of pearl perch larger than 40 cm FL (25%) in Queensland than in NSW (13%).

Estimation of age

Pearl perch otoliths were relatively difficult to interpret due to the broad and diffuse nature of the opaque zonation and the subtle translucent marks between them (Fig. 2). This diffuse zonation was reflected by a relatively high coefficient of variation between counts of 9.7%, with 63% of fish assigned the same age and 26% differing by 1.

Counts of daily growth increments in three small fish (9–12 cm FL) ranged between 250 and 300. The distance from

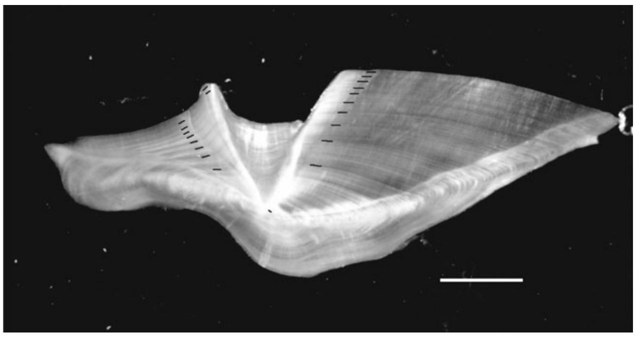

Fig. 2. Sectioned otolith from a pearl perch, *Glaucosoma scapulare*, showing 10 annuli viewed using reflected light. Scale bar = 2 mm

the core of these small otoliths to their edge (mean ± SD; 1.18 ± 0.08 mm) was similar to that measured from the core of larger otoliths to the first annular mark (1.39 ± 0.12 mm), thus supporting the interpretation of the first annulus in sections of larger specimens (see also Fig. 2).

Further evidence that 9–12 cm pearl perch were approx. one year old was obtained from records of experimental prawn trawl surveys conducted by the FRV *Kapala* in northern NSW between 1990 and 1996. Length frequency data indicated that pearl perch were present at about 4–7 cm FL during the second quarter of the calendar year (April to June) (Fig. 3). These 0+ recruits grew throughout the year to attain a size of around 9–12 cm by the following summer

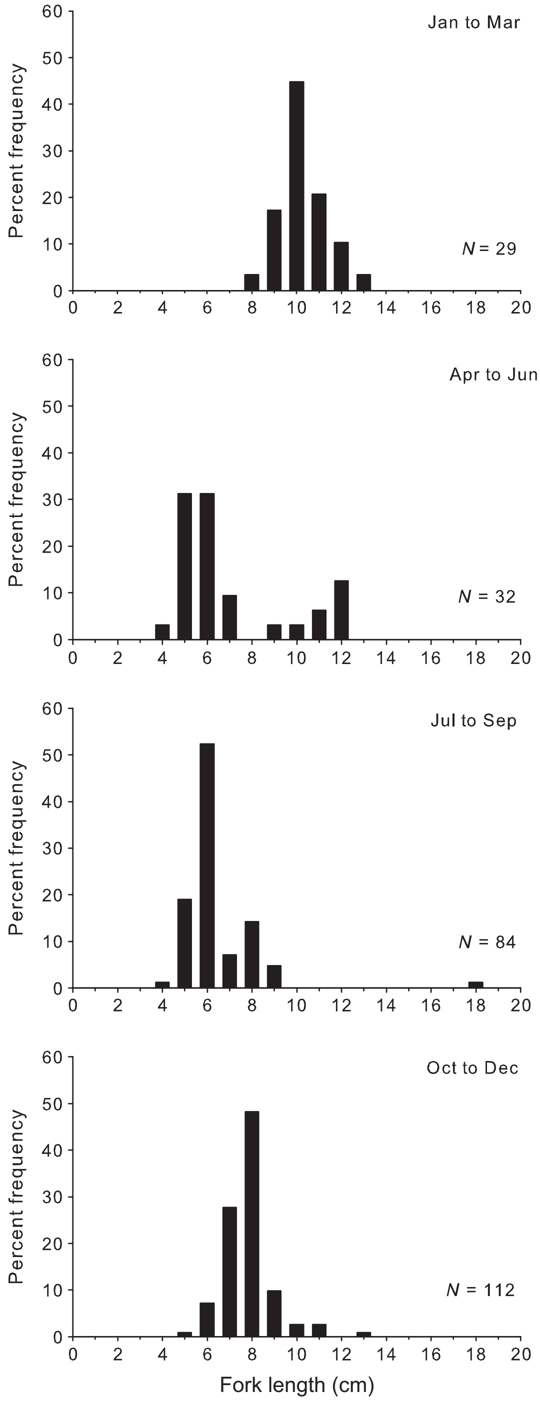

Fig. 3. Length frequency of pearl perch, *Glaucosoma scapulare*, captured by FRV Kapala while towing prawn trawl nets. Data pooled for each calendar year quarter, 1990–1996 surveys

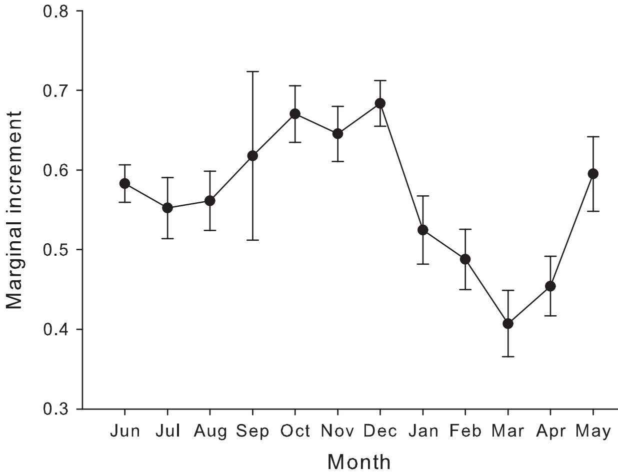

Fig. 4. Mean (± standard errors) monthly marginal increments for pearl perch, *Glaucosoma scapulare*, aged 4 years and more, New South Wales, 2005–2006 and Queensland, 1992–1996, combined. n = 322

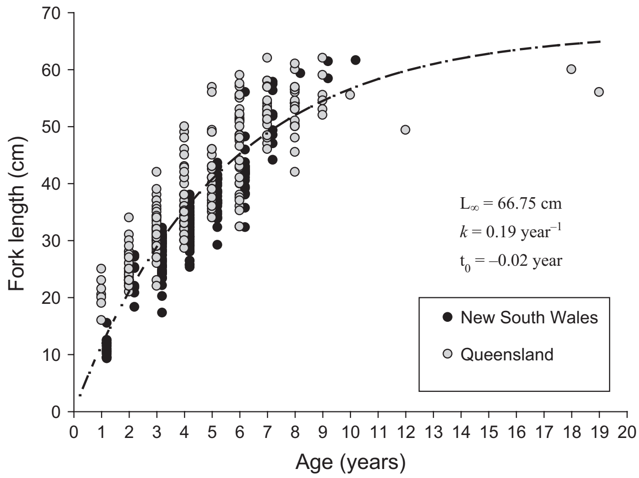

Fig. 5. Size-at-age data for pearl perch, *Glaucosoma scapulare*, with fitted von Bertalanffy growth curve. New South Wales data slightly offset for clarity

(Jan-Mar) and were the only cohort present in the trawl samples from this period.

The monthly trends in mean marginal increment ratios initially showed no obvious annual periodicity. However, once data were limited to fish aged 4 and greater the trend in mean monthly marginal increment ratios was consistent with annual periodicity (Fig. 4). The data showed a pattern of higher values during the austral winter/early summer and lower values during the late summer/autumn, suggesting that opaque zones are generally scored as being completed by January to March.

Growth rates

Comparison of the VBGF fitted to size-at-age data for each sex indicated no significant difference between males and females (ARSS, $F_{3,\ 123} = 0.09$, $P > 0.05$). Comparison of growth curves from NSW and Queensland, across equal age ranges, indicated significant differences (ARSS, $F_{3,\ 511} = 38.6$, $P < 0.001$). VBGF parameters for pearl perch from Queensland were $L_\infty = 61.79$ cm FL, $k = 0.24$ year^{-1} and $t_0 = -0.01$ year and from NSW were $L_\infty = 79.31$ cm FL, $k = 0.13$ year^{-1} and $t_0 = -0.02$ year. VBGF parameters best describing the growth of pearl perch within the population as a whole (data from Queensland and NSW combined) were $L_\infty = 66.75$ cm FL, $k = 0.19$ year^{-1} and $t_0 = -0.02$ year (Fig. 5). Pearl perch reach an average of approx. 12 cm FL after 1 year, 21 cm FL after 2 years and 29 cm FL after 3 years.

The oldest pearl perch sampled from NSW were 9 and 10 years of age and 61.4 and 61.6 cm FL, respectively; the oldest fish sampled from Queensland were 18 and 19 years of age and 60 and 56 cm FL, respectively.

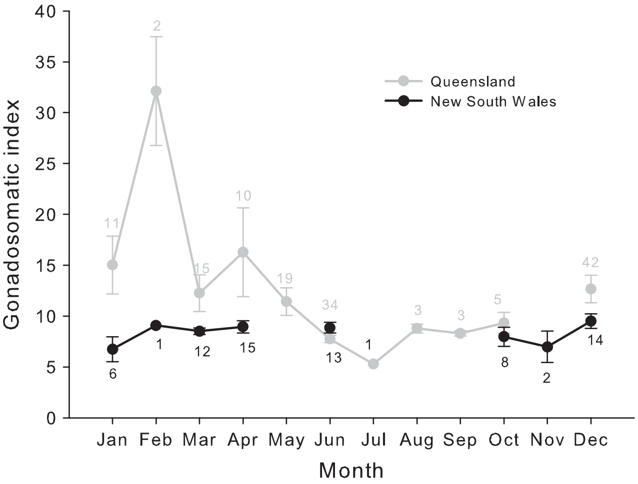

Fig. 6. Mean (± standard errors) monthly gonadosomatic indexes for female pearl perch, *Glaucosoma scapulare*, sampled from New South Wales, 2005–2006 and Queensland, 1994–1996. Numbers represent sample sizes

Reproductive activity

Pearl perch from Queensland waters displayed elevated mean GSI levels during summer/autumn, with a definite peak during February, noting the small sample size during that month. Pearl perch from NSW waters had relatively low mean GSI levels, similar to those of fish from Queensland waters outside of the reproductive season, in all months sampled (Fig. 6).

Age composition in the landed catches

The most abundant age class in commercial landings was 4 years in both Queensland and NSW (Fig. 1). The majority of landings were between 3 and 6 years of age in each state (Queensland ~ 83% and NSW ~ 93%). There was a greater percentage of fish above 6 years of age in landings from Queensland (~ 9%) than in landings from NSW (~ 4%).

Discussion

This study is the first to examine age-based demographics of pearl perch across its distributional range. Whilst acknowledging that the data from Queensland and NSW were collected approx. a decade apart, the insights into the demographics of the entire pearl perch population that combining these data has allowed are substantial. Despite this, it is important that temporal changes in age-related life-history traits and population structure are considered as alternative hypotheses to those discussed below regarding population dynamics of pearl perch.

Annuli in the otoliths of pearl perch (*Glaucosoma scapulare)*, particularly the first few, were broad and diffuse, making interpretation in some individuals difficult, resulting in a relatively high mean CV when repeating age counts. However, the marginal increment analysis demonstrated that opaque zones in these otoliths are deposited once each year and so can be used to estimate age. Opaque zones were formed during the late austral winter/early summer and were scored as being completed by late summer/autumn. This pattern is consistent with the timing of opaque zone formation in otoliths of other inshore species in this region (Stewart and Hughes, 2007; Morton et al., 2008). The first annulus was confirmed through counting daily growth increments in small pearl perch and supported by following modal length frequency distributions of small pearl perch captured in trawl nets. These small pearl perch were first observed in catches at about 4–7 cm FL during the second quarter of the calendar year (April to June), an observation consistent with a summer spawning period in Queensland and a larval period similar to other glaucosomatids of around 40 days (Pironet and Neira, 1998). Growth of these small fish to around 12 cm FL by the following summer period was consistent with the size at age predicted by our growth modelling.

The age and growth characteristics of pearl perch indicate that this species is similar to its congenerics in being relatively long-lived (>19 years) and slow growing (VBGF growth parameter $k < 0.2$ year^{-1}). It is more similar to the northern pearl perch in both asymptotic maximum sizes and maximum recorded ages ($L_\infty = 66.75$ cm FL and 19 years for pearl perch and $L_\infty = 52.83$ cm FL and 26 years for northern pearl perch) than for the western Australian dhufish ($L_\infty = 92.9$ cm FL and 41 years). In addition, we found no significant differences in growth between sexes for pearl perch as also reported for the northern pearl perch (*G. buergeri*) (Newman, 2002). In contrast, Hesp et al. (2002) reported significant differences in growth between sexes for the western Australian dhufish (*G. hebraicum)*, with females having a greater L_∞ than males (102.5 cm FL compared to 92.9 cm FL, respectively).

We found significant differences in the growth rates of pearl perch from the northern part of its range (Queensland) when compared to those from the southern part of its range (NSW). These differences occurred despite the relatively small latitudinal distribution of this species (~ 1000 km) and the relatively minor distance between sampling in each state (~ <600 km). The otoliths from both states were read by the same reader so that there were no differences in otolith interpretation. We suggest three alternative hypotheses for this observation. One hypothesis to explain the faster growth rate in Queensland waters relates to the ~ one decade difference in when otoliths were collected. However, it seems unlikely that such a significant decline in growth rate would occur in only one decade within a species with the longevity and generation time of pearl perch (Enberg et al., 2011). The second hypothesis is that pearl perch grow faster in the northern part of their range due to higher water temperatures, a feature well documented for many fish species (Pedersen and Jobling, 1989; Imsland et al., 1996), including several from eastern Australia such as *Sillago ciliata* (Cuvier, 1829) (Stocks et al., 2011), *Girella tricuspidata* (Quoy & Gaimard, 1824) (Gray et al., 2010) and *Arripis trutta* (Forster, 1801) (Stewart et al., 2011). Thirdly, pearl perch in Queensland and NSW may represent two discrete populations with differing growth rates. This third scenario seems unlikely given the influence of the dominant, southerly flowing Eastern Australian Current in this area (Ridgway and Dunn, 2003). Rather, we suggest that pearl perch may have a life-history strategy similar to many other species off eastern Australia that move northwards with increasing age to mature and spawn, their larvae being distributed southwards by the Eastern Australian Current e.g. *Arripis trutta* (Stanley, 1978); *Melicertus plebejus* (Hess, 1865) (Montgomery, 1990); *Ibacus chacei* (Brown and Holthuis, 1977) (Stewart and Kennelly, 1998). Unfortunately we have little understanding of the movement patterns of pearl perch, however the fact that almost no reproductively active fish were sampled from NSW waters during the present study, which sampled large fish throughout the year, suggests that pearl perch may move into more northern waters to mature and spawn. More work is clearly needed on the reproductive biology and patterns of movement of pearl perch to test this model.

The sizes and ages of pearl perch landed in the commercial fisheries in each state were different, with a greater percentage of fish larger (>40 cm FL) and older (>6 years) in the Queensland catches. One hypothesis to explain this observation, as discussed above, is that these differences are due to the spatial demographics of the population, with fish from NSW moving northwards into Queensland waters as they get older, possibly to reproduce. This is supported by the fact that the oldest fish (18 and 19 years old) were from Queensland waters and were substantially older than the oldest fish sampled in NSW (10 years). An alternative hypothesis is that pearl perch have been subjected to a long history of exploitation that has depleted the larger and older animals, and the latitudinal differences observed were a result of the ~ one decade difference in when samples were collected from each state. Age-class truncation, defined as the removal of older age classes in a population through fishing, has been recognized as reducing population resilience and is a sign of overfishing (Longhurst, 1998, 2002; Beamish et al., 2006; Stewart, 2010). The fact that we sampled fish of up to 19 years of age and that the age composition of the Queensland catch had very few fish >8 years, may indicate that age-class truncation had occurred prior to that sampling in the mid-1990s. The Queensland sampling in the mid-1990s may therefore have been done on an already age-truncated population and the decline may have continued through to the sampling during 2005 and 2006 in NSW.

Similar to congeneric species, pearl perch have relatively slow growth rates and moderate longevity, characteristics that may make them vulnerable to overfishing. The variation in age-based demographics of pearl perch demonstrated in the present study suggests a complex population structure that requires better understanding before informed management can be implemented. In particular, further research is needed on the patterns of movement and reproduction of pearl perch in order to develop a life-history model of this species. Further, concurrent samplings for age-based assessments are clearly needed at either end of the pearl perch distribution to support the hypotheses regarding population dynamics presented here.

Acknowledgements

We thank Mr Ken Graham for the FRV *Kapala* trawl length data and Miles Yeates who assisted in the laboratory. We gratefully acknowledge the assistance of all those fishers who allowed us to regularly sample their catches. Drs Kevin Rowling and Michael Lowry provided useful comments on drafts of the manuscript.

References

Andersen, C., 2006: Annual status report 2006 - Rocky Reef Fin Fish Fishery. Department of Primary Industries and Fisheries, Brisbane, p. 14.

Beamish, R. J.; McFarlane, G. A.; Benson, A., 2006: Longevity overfishing. Prog. Oceanogr. **68**, 289–302.

Campana, S. E.; Thorrold, S. R., 2001: Otoliths, increments and elements: keys to a comprehensive understanding of fish populations? Can. J. Fish. Aquat. Sci. **58**, 30–38.

Cayré, P.; Laloë, F., 1986: Review of the gonad index (GI) and an introduction to the concept of its 'critical value': application to the skipjack tuna, *Katsuwonus pelamis*, in the Atlantic Ocean. Mar. Biol. **90**, 345–351.

Chen, Y.; Jackson, D. A.; Harvey, H. H., 1992: A comparison of von Bertalanffy and polynomial functions in modelling fish growth data. Can. J. Fish. Aquat. Sci. **49**, 1228–1235.

DEEDI, 2011: Stock status of Queensland's fisheries resources 2009–2010. Department of Employment and Economic Development and Innovation, Brisbane.

Enberg, K.; Jørgensen, C.; Dunlop, E. S.; Varpe, Ø.; Boukal, D. S.; Baulier, L.; Eliassen, S.; Heino, M., 2011: Fishing-induced evolution of growth: concepts, mechanisms, and the empirical evidence. Mar. Ecol. **33**, 1–25.

Gray, C. A.; Ives, M. C.; Macbeth, W. G.; Kendall, B. W., 2010: Variation in growth, mortality, length and age compositions of harvested populations of the herbivorous fish *Girella tricuspidata*. J. Fish Biol. **76**, 880–899.

Hesp, S. A.; Potter, I. C.; Hall, N., 2002: Age and size composition, growth rate, reproductive biology, and habitats of the West Australian dhufish (*Glaucosoma hebraicum*) and their relevance to the management of this species. Fish. Bull. **100**, 214–227.

Hutchins, B.; Swainston, R., 1986: Sea fishes of southern Australia. Swainston Publishing, Perth, Pp 180.

Imsland, A. K.; Sunde, L. M.; Folkvord, A.; Stefansson, S. O., 1996: The interaction between temperature and size on growth of juvenile turbot. J. Fish Biol. **49**, 926–940.

Kimura, D. K., 1977: Statistical assessment of the age-length key. J. Fish. Res. Board Can. **34**, 317–324.

Lai, H.-L., 1993: Optimal sampling design for using the age-length key to estimate age composition of a fish population. Fish. Bull. **91**, 382–388.

Longhurst, A., 1998: Cod: perhaps if we all stood back a bit? Fish. Res. **38**, 101–108.

Longhurst, A., 2002: Murphy's Law revisited: longevity as a factor in recruitment to fish populations. Fish. Res. **56**, 125–131.

Marriott, R. J.; Adams, D. J.; Jarvis, N. D. C.; Moran, M. J.; Newman, S. J.; Craine, M., 2010: Age-based demographic assessment of fished stocks of *Lethrinus nebulosus* in the Gascoyne Bioregion of western Australia. Fish. Manag. Ecol. **18**, 89–103.

McKay, R. J., 1997: Pearl perches of the world (Family Glaucosomatidae) . FAO Fish. Synop. no. 125. FAO, Rome, p. 26.

Montgomery, S. S., 1990: Movements of juvenile eastern king prawns, *Penaeus plebejus*, and identification of stock along the east coast of Australia. Fish. Res. **9**, 189–208.

Morton, J. K.; Gladstone, W.; Hughes, J. M.; Stewart, J., 2008: A comparison of the life histories of three co-occurring wrasses (Teleostei: Labridae) in coastal waters of south-eastern Australia. Mar. Freshwat. Res. **59**, 560–574.

New South Wales Department of Primary Industries, 2006: Fishery management strategy for the NSW Ocean trap and line fishery. NSW Department of Primary Industries, Cronulla, p. 105.

Newman, S. J., 2002: 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. J. Appl. Ichthyol. **18**, 95–101.

Pedersen, T.; Jobling, M., 1989: Growth rates of large, sexually mature cod, *Gadus morhua*, in relation to condition and temperature during an annual cycle. Aquaculture **81**, 161–168.

Pironet, F. N.; Neira, F. J., 1998: Hormone-induced spawning and development of artificially reared larvae of the West Australian dhufish, *Glaucosoma hebraicum* (Glaucosomatidae). Mar. Freshwat. Res. **49**, 133–142.

Ridgway, K. R.; Dunn, J. R., 2003: Mesoscale structure of the mean East Australian Current System and its relationship with topography. Prog. Oceanogr. **56**, 189–222.

Rowling, K.; Hegarty, A.; Ives, M., 2010: Status of fisheries resources in NSW 2008/2009. NSW Industry and Investment, Cronulla. 392 pp.

Stanley, C. A., 1978: Area of distribution, movements, age composition and mortality rates of the Australian salmon population in Tasmania, Victoria and New South Wales. Aust. J. Mar. Fresh. Res. **29**, 417–433.

Stewart, J., 2010: Evidence of age-class truncation in some exploited marine fish populations in New South Wales, Australia. Fish. Res. **108**, 209–213.

Stewart, J.; Hughes, J. M., 2007: Age validation and growth of three commercially important hemiramphids in south-eastern Australia. J. Fish Biol. **70**, 65–82.

Stewart, J.; Kennelly, S. J., 1998: Contrasting movements of two exploited Scyllarid lobsters of the genus *Ibacus* off the east coast of Australia. Fish. Res. **36**, 127–132.

Stewart, J.; Hughes, J. M.; McAllister, J.; Lyle, J.; MacDonald, M., 2011: Australian salmon (Arripis trutta): Population structure, reproduction, diet and composition of commercial and recreational catches. Industry & Investment NSW – Fisheries Final Report Series No. 129. 257pp.

Stocks, J.; Stewart, J.; Gray, C. A.; West, R. J., 2011: Using otolith increment widths to infer spatial, temporal and gender variation in the growth of sand whiting *Sillago ciliata*. Fish. Manag. Ecol. **18**, 121–131.

Author's address: John Stewart, Fisheries NSW, Sydney Institute of Marine Science, Chowder Bay Road, Mosman, NSW 2088, Australia.
E-mail: John.Stewart@dpi.nsw.gov.au