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The Quest for Fisheries Sustainability: Age, Growth and Maturity of Golden Trevally (Gnathanodon speciosus) in Australia

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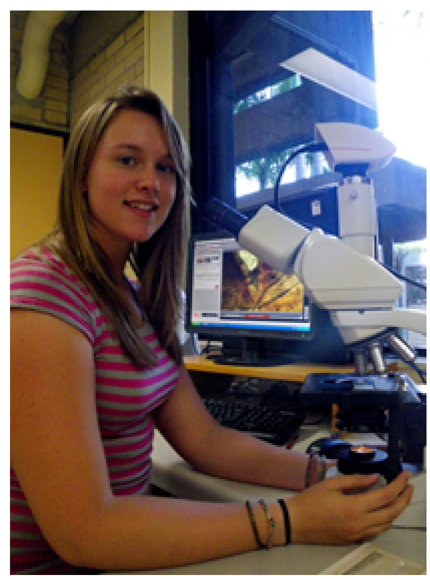
The Quest for Fisheries Sustainability: Age, Growth and Maturity of Golden Trevally (*Gnathanodon speciosus*) in Australia

—Elise Koob (Edited by Kevin Anderson)

Whether it is the good taste, health benefits or the result of the most recent fad, seafood has become one of the most popular and highly demanded food products in the world. From salmon to tuna, the catch and demand of fish have continued to increase in recent years. With some species of tuna, such as Atlantic bluefin, reaching prices as high as $370/lb, it is obvious why they are an appealing target for commercial fishers (Yamaguchi, 2009). Although not all fish attract such extravagant prices, demand in general has increased significantly in recent years. For example, total global capture of fish since the 1960s has increased from approximately 30 to 90 million tons (FAO Fisheries Circulars, 2009) as a result of a doubling in human population and advances in harvesting technology (Population Reference Bureau, 2009). Such huge increases in fish harvests lead to questions of long-term sustainability: whether these stocks can sustain rising demand or if over-fishing is unavoidable. Unfortunately, catch trends and inadequate management policies appear to be responsible for over-fishing, and it is evident we are depleting some fish stocks.



The author counting golden trevally otolith rings through a microscope at CSIRO.

My own love of seafood and recent awareness of species exploitation led me to research fish population dynamics, the factors that can lead to over-fishing, and possible mitigation measures. During the summer of 2010, I went to Brisbane, Australia with the help of a Summer Undergraduate Research Fellowship (SURF Abroad) to study the large pelagic fish, golden trevally (*Gnathanodon speciosus*). My project, directed by scientists at Australia's *Commonwealth Scientific and Industrial Research Organization* (*CSIRO*), was part of a larger study to collect data on the age, growth and maturity of coastal large pelagic fishes, including golden trevally, cobia and longtail tuna. The importance of golden trevally to the food industry and recreational fisheries has raised concern about the species' future sustainability. However, little is known about their growth and reproductive dynamics, and few regulations currently exist to control their exploitation. My project aimed to improve our understanding of this species' growth dynamics and longevity by collecting age and growth data. As a result of integrating my data with reproductive data collected by scientists at CSIRO, we discovered that the age at which this species becomes sexually mature is considerably older than once thought. Such a finding is extremely important for setting precautionary management measures to prevnt growth over-fishing, which is the harvesting of small fish before they are mature enough to reproduce and contribute to the next generation.

Over-fishing: A Global Problem

Globally, the population sizes of many fish species in the oceans have decreased dramatically, and in some cases, these declines have resulted in the total collapse of fisheries. For example, the Atlantic cod fishery off Newfoundland collapsed in 1993, which resulted in a moratorium on all cod fishing in the northeast Atlantic. The Atlantic cod collapse was due to growth over-fishing and the increasing use of extremely efficient fishing gear (Myers & Hutchings, 1997). In 2003, 29% of global fisheries were in a state of collapse (Worm, et al., 2006). More recent estimates by the United Nations Food and Agriculture Organization state that, in 2009, nearly 70% of the world's fisheries were over-exploited or in a state of collapse (FAO Fisheries Circulars, 2009). These statistics support current concerns and regulations about the rapidly declining stock abundance of many popular commercial and recreational fish species. For example, a recent, widely publicized decision by international agencies is to cut the total yearly quota for bluefin tuna in hopes of preventing a severe collapse similar to that of the Atlantic cod (Yamaguchi, 2009).

Fishing Sustainably: From Biology to Conservation

Although the implementation of sustainable fishing practices has been debated for years, the concept of maximum sustainable yield (MSY) has been widely accepted as a goal to be established for many fished populations. MSY is the theoretical maximum amount of fish that can be harvested while still allowing the population to attain its maximum growth rate (Punt & Smith, 2001). Unfortunately, estimations of MSY can be highly uncertain, particularly if data on population dynamics is unavailable or poorly validated. For example, it had been assumed that a deep sea fish, orange roughy (*Hoplostethus atlanticus*), had a short lifespan until research showed that they can live for nearly 150 years and reproduce only when they are twenty to forty years of age. Unfortunately, their stocks were rapidly depleted before more reliable biological data was collected (Mace, Fenaughty, & Coburn, 1990).

Golden trevally (Gnathanodon speciosus) *swimming at a coral reef in Australia (Ian McLeod, CSIRO).*

One management strategy that is used to attain MSY is the implementation of a minimum legal length (MLL). This strategy sets the minimum size at which a fish can be legally removed from a population, and this size is usually defined as the length at which 50% of the population is sexually mature. Along with growth overfishing, the excess removal of immature fish, recruitment overfishing is the over-harvesting of larger older fish in a population. This means there will be too few mature fish remaining to produce enough offspring to sustain the population (S. Griffiths, personal communication, 2010). Reliable biological information on fish species, such as the age of these fish at certain lengths, is important for fisheries managers in order to balance exploitation across appropriate age classes of the population. This would mean concentrating fishing efforts on mid-sized fish to avoid both growth over-fishing and recruitment over-fishing.

Counting Rings: Collecting Data on Golden Trevally

The lack of age and growth data for golden trevally is a concern for fishery managers, given the growing importance of the species to commercial and recreational fisheries. This economically important species is found in the Indo-Pacific region and reaches a length and weight of 110 cm and 15.0 kg respectively (Randall, Allen, & Steen, 1997). Golden trevally are bottom feeders, consuming molluscs and crustaceans, but also feed on small schooling fishes near surface waters.

The sample I worked with, 212 golden trevally, was collected prior to my arrival from commercial fisheries using gillnets and from recreational fisheries using hook and line. I began my project by taking basic measurements of the fish collected, such as whole weight and fork length (snout to the base of the tail fin), to be used when relating age and growth data. I aged the fish using sagittal otoliths (inner ear bones), where layers of calcium carbonate are continually deposited as the fish grows. Aging is possible because these layers generally alternate between opaque and translucent depending on the season of growth, e.g., opaque rings are laid down in the winter when growth is slowest (Griffiths, Fry, Manson, & Lou, 2009). This means that one opaque layer and one translucent layer theoretically indicate one year in the fish's life. I

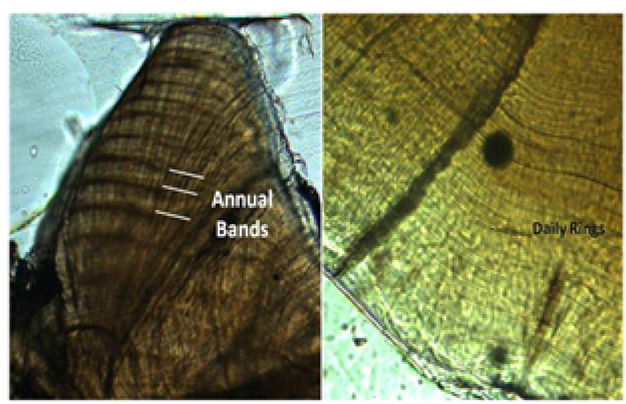


Fig. 1. Annual growth bands in a portion of a golden trevally otolith (left), and daily growth bands/rings along the outside edge of a golden trevally otolith (right).

embedded otoliths in a transparent resin and cut thin sections in order to read the annual bands under a microscope. I counted annual bands in fish with more than two presumed annual growth bands, while daily increments were counted in younger fish due to a lack of clear annual bands. (Figure 1) Each fish was aged twice; if discrepancies were present, a third count was made.

In addition to estimating the age of golden trevally, I and the CSIRO staff analyzed reproductive data to determine the age at which these fish are sexually mature and therefore able to contribute to the population. We examined only females because ovary development is considered to be most indicative of spawning activity (Van der Velde & Griffiths, 2010). We analyzed the developmental stages of female reproductive organs by taking tissue from ovaries. These tissue portions were embedded in wax, sectioned, stained and observed through a microscope. Reproductive development was determined based on size, shape and presence of egg cells (oocytes).

Unexpected Outcomes: An Age Worth Considering

Growth curves are important for understanding the rate at which a species grows in order to estimate age at a particular length and determine a theoretical maximum length and age. The von Bertalanffy growth function was used for this data as it is considered to be the most biologically meaningful representation of growth in larger species of fish such as golden trevally. As seen in Figure 2, additional large fish need to be collected to determine the true point at which growth ceases, indicative of true maximum length and age. However, the largest fish in a population are difficult to obtain due to high natural and fishing mortality. It has been previously assumed that tropical fish species like golden trevally grow, mature and die relatively quickly—around seven to ten years (S. Griffiths, personal communication, 2010). However, the curve from my data conflicts with this assumption by showing that this species grows more slowly and lives longer than expected— up to about fifteen years.

Using this length-at-age relationship combined with the reproductive data, a graph was plotted to show the length at which 50% of the females would be able to spawn, thereby contributing to next year's stock. The graph of Figure 3 shows that females are sexually mature at a relatively large length (537 mm). By using my previous growth curve, I estimated the age at maturity to be approximately six years.

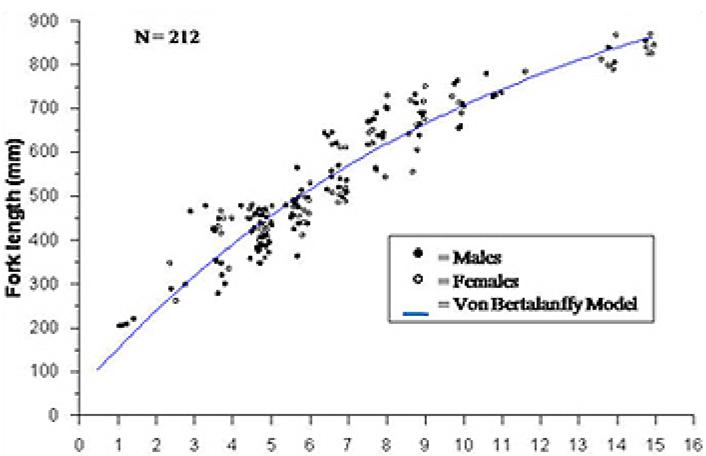


Fig. 2. Age and length curve with von Bertalanffy model fit for golden trevally. Minimum and maximum ages were 0.45 years (65 mm) and 15 years (861 mm), respectively. N = number of fish in sample.

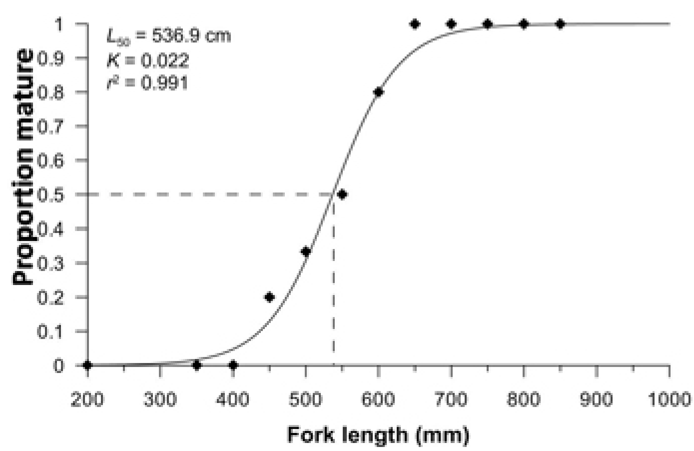


Fig. 3. Proportion of mature females by length for golden trevally. Length at which 50% of females mature is 537 mm (Shane Griffiths, 2010).

Implications: Results to Regulations

What do all these data actually mean relative to the sustainability of the golden trevally fishery? As mentioned, a minimum legal length (MLL) is one of the most popular and most easily implemented tools used to manage fishing impacts. The results of my study can be directly used to support this management measure. Australia currently does not have a MLL for golden trevally, but implementing one would assist in preventing any decline in population numbers from growth over-fishing. Ideally, the MLL should be close to a length at which 50% of the population is mature, i.e., above ~537 mm. This in turn would help to ensure that the fish being removed have had the opportunity to spawn and contribute to the population. Fishing gear restrictions are also closely related to the use of MLL as a recreational and commercial management strategy. Once a MLL is set, recreational fishers would have to use particular hooks or lures that are selective for larger fish sizes or ensure that small fishes are released unharmed; while commercial fishers would need to use nets with larger size mesh to allow immature fish to escape.

The preservation of predatory fish like golden trevally is vital to the health of the ecosystem as a whole. Ecosystem-based fisheries management is a relatively new idea which calls for managing an entire ecosystem rather than a specific target species. Such management aims to sustain healthy ecosystems by considering how the harvesting of one species might impact others and looks at how an ecosystem works as a whole (Pikitch, et al., 2004). Ecosystem models are used to identify food web linkages among species in a certain ecosystem. My data can be used to build these models for golden trevally. Top predators, such as golden trevally, are extremely important in shaping these systems, and changes in their stock abundances can have rippling effects further down the food web (Griffiths, Kuhnert, Fry, & Manson, 2009).

Australia: Personal Curiosity

One may ask why I went half way around the world when I could have found somewhere closer to UNH to carry out a similar project. I was interested in experiencing research in a different country and also wanted to find out if global issues are perceived differently from place to place. Through my experiences abroad, I found that the concerns for conservation and management are similar to what I have been exposed to in the US. However, the management of fisheries appears to have been more effective in Australia than in the US in terms of policy implementation. The research at the CSIRO is based on management and conservation needs at the start of a fishery before substantial issues arise, whereas other factors (such as politics) tend to become more of an issue in the US. However, both countries use similar management strategies, such as input controls (restricting fishing effort by limiting boats or gear) or output controls (annual quotas) depending on the species.

This research project interested me because it has direct implications for fisheries sustainability, but I am surprised at the larger impact it has had on me personally. Throughout my years in college, I have been excited about conducting research because I knew it is what I want to do in the future. However, as many college students experience, I was completely lost as to what area I was interested in—a needed piece of information for a prospective graduate school student. However, after a couple weeks of being at CSIRO, there it was—the eagerly awaited light bulb. My interest in fisheries research hit me as I was tediously working through modeling problems my mentor insisted I do longhand. Of all the moments to strike me, I never expected it would be then, doing math. Really?! After my experiences with this project, it was obvious to me that fisheries science is what I am interested in. Who knew I would finally figure it out, half way around the world. Graduate school—bring it on!

I would like to thank my project mentors, Shane Griffiths and Gary Fry, for making my experience with this project possible and guiding me through each step. Thank you to my faculty mentor, Molly Lutcavage, for putting me in contact with Shane and supporting me throughout the whole process from beginning to end. I would also like to thank everyone at CSIRO, who welcomed me with open arms and taught me new and amazing things. This trip would not have been possible without the help of everyone at the Hamel Center for Undergraduate Research and the SURF Abroad program. Thank you for this opportunity; it has truly helped pave the path for my future. Thank you to my friends and family, who let me disappear half way around the world for six months: your confidence in me and words of encouragement helped me so much along the way.

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Author Bio

The pursuit of her passion for marine sciences has led senior ***Elise Koob*** *far from her hometown of Scotia, New York. With funding from a Summer Undergraduate Research Fellowship Abroad (SURF) from the University of New Hampshire, Elise traveled to Cleveland, Australia, to study the maturation, reproduction, and conservation of an important species of fish, golden trevally. Although Elise has always been interested in the research process, her SURF served as her introduction to the field of fisheries management research, which blends her major of marine and freshwater biology with her minor in environmental conservation. Elise found it rewarding to learn not only how to research the biological development of a species, but also how to convert that information into sustainable fishing practices. Graduating in May of 2011 with a Bachelor of Science, Elise plans to continue on to graduate school and pursue a career in fisheries science research.*

Mentor Bios

Dr. ***Molly Lutcavage****, currently Research Professor in the Department of Environmental Conservation at the University of Massachusetts-Amherst, served as Elise's mentor during her time as Associate Research Professor on the University of New Hampshire faculty. Elise assisted with several projects in Dr. Lutcavage's Large Pelagics Research Lab before approaching her with the idea of a SURF-Abroad. Dr. Lutcavage was* *essential to the formation of Elise's project, advising Elise on her interests and goals and connecting Elise with her foreign mentor.*

Dr. Lutcavage is glad to see Elise write about her work in Inquiry, and said: "Any writing that has feedback and potential for learning has got to be good. My dilemma in reviewing her Inquiry report was how much to edit and guide her to a more conventional science report. This might be one of very few science writing outlets where she has an opportunity to write without much restraint, and can include personal points of view about traveling and people." Dr. Lutcavage advised Elise, however, to be as precise and quantitative as possible. "She has a lot of talent and will blossom as a scientist with good mentoring," Dr. Lutcavage concluded.

Elise's foreign mentor, Dr. ***Shane Griffiths****, is a Research Scientist at Australia's Commonwealth Scientific and Research Organization (CSIRO), Division of Marine and Atmospheric Research, located in Cleveland, Australia. Dr. Griffiths specializes in recreational fisheries research as well as the population dynamics of pelagic fish and pelagic ecosystems. At an international symposium in California, Elise's University of New Hampshire mentor, Dr. Molly Lutcavage, met Dr. Griffiths and asked him if he would be willing to mentor Elise in her summer research. Dr. Griffiths agreed, and said he "found it very rewarding" to assist Elise in the planning, completion, and presentation of her research. He was actively involved in the writing of Elise's article.*