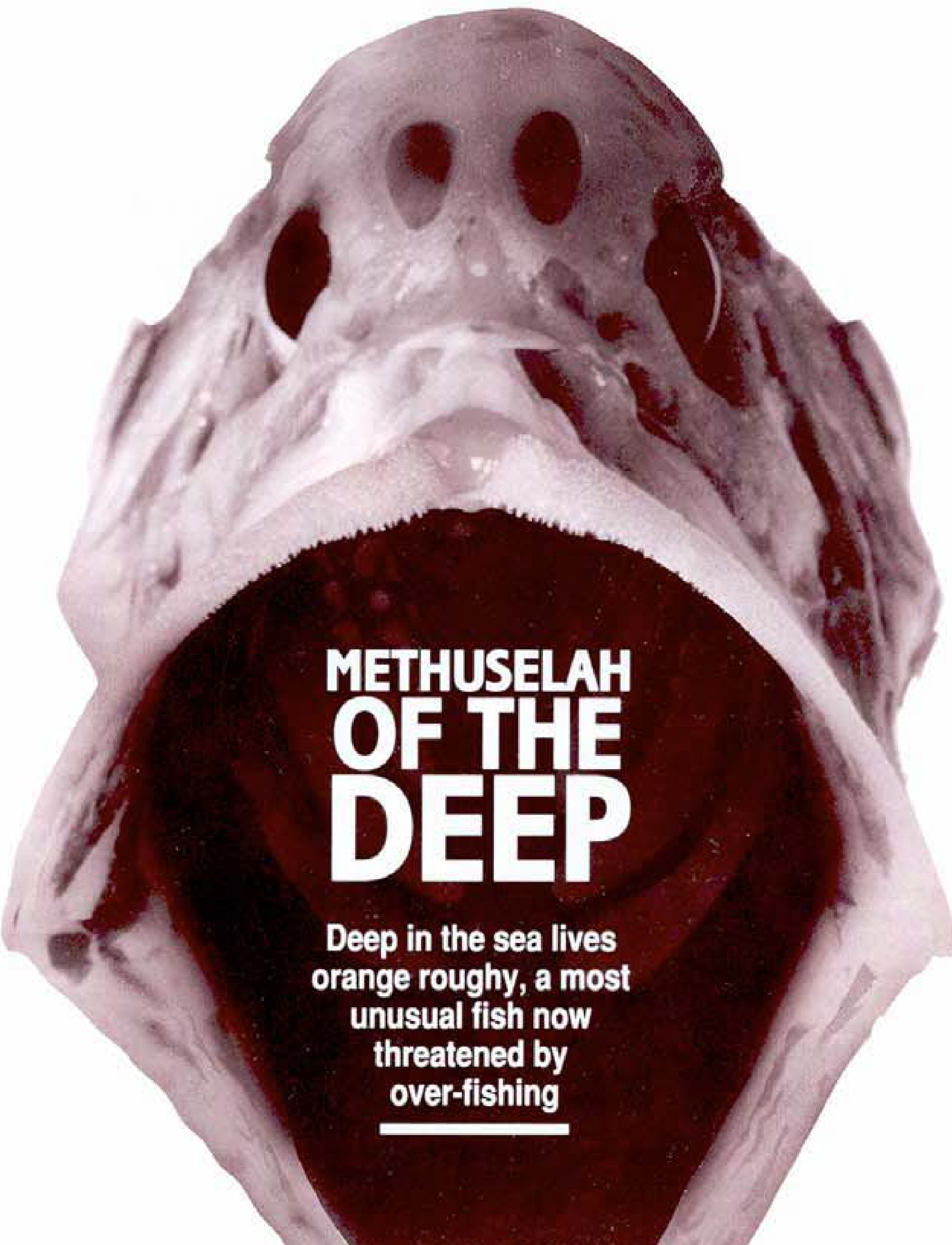


Photo: Thor Carter

METHUSELAH OF THE DEEP

Deep in the sea lives orange roughy, a most unusual fish now threatened by over-fishing

You wouldn't normally expect a piece of fish that you are eating to be older than your most aged acquaintance, but, if the fish is orange roughy, it could well be. Most of the fish we eat, like the other animals we use for food, have life spans considerably less than ours. Orange roughy, the quaintly named fish that has only recently arrived in our shops and restaurants — where it is often called deep-sea perch — is a striking exception.

Although the fish as a species had been known for some time from its occurrence in small numbers in the Northern Hemisphere (with the scientific name *Hoplostethus atlanticus*), sufficient quantities to make it a commercial proposition were discovered only about 10 years ago by New Zealanders, and shortly thereafter near Tasmania.

Australia's fishing fleet started taking the new fish in 1985, with a catch of 400 tonnes. But then fishermen found dense aggregations of roughy off Tasmania's north-western coast, and elsewhere shortly afterwards, and catches rose to 4600 tonnes a year later. They have been increasing ever since.

Thor Carter

On board a research vessel, a CSIRO scientist gathers data on size and weight of whole fish and various organs.

One of the reasons that orange roughy's potential remained unknown for so long is that it lives at great depth. Most commercial fishing takes place on the continental shelf — in terms of nutrients and biomass, the richest part of the ocean — which extends down to about 200 m. But orange roughy lives at a depth of 1000 m or more.

It differs from most commercial fish in other ways, too. The first facts that scientists need to know to advise on effective management of a commercial fish species include the animal's life span and the age at which it reaches sexual maturity. Usually, the otolith, a small bone in the ear, helps measure the aging process. As with the trunk of a tree, each year a new 'shell' of growth appears, and slicing the bone and counting the rings can give a fair estimate of a fish's age because, unlike mammals, fish continue to grow throughout their lives. (The technique is not foolproof, as some years may see no growth ring or rings may be added more often than annually.)

Otolith observations on orange roughy gave scientists a number of quite different results. Early estimates for the age of sexual maturity ranged from 5 to 12 years. However, other researchers studying very young fish concluded that they grew only slowly and estimated that 20 years would be the age at maturity. A late maturing implies that a population can take a long time to replace itself — a vital consideration if you want fish to be available forever.

Because of the importance to the industry of accurate age determinations, Dr Gwen Fenton of the Zoology Department at the University of Tasmania, in collaboration with Dr Steve Short of the Australian Nuclear Science and Technology Organisation, adopted another technique. She measured the ratio of isotopes of lead and radium in otoliths.

The technique utilises the fact that an isotope of radium occurring naturally in small amounts in the environment is incorporated into the otolith during its growth. This radium-226, with a half-life of 1600 years, decays slowly into an isotope of lead (lead-210), with a half-life of 22·3 years. The decay rates of the two isotopes (which are known) determine their ratio in the otolith. Measuring that ratio, therefore, can tell us how much time has passed since the radium-226 was incorporated.

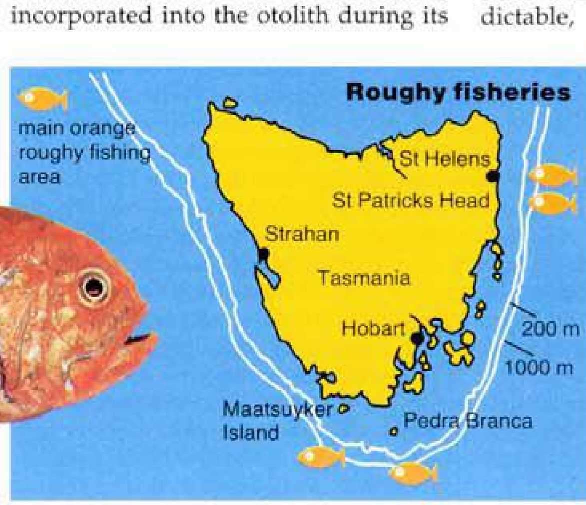
Of course, like any other technique, this one depends on certain assumptions, such as that the otolith takes up radium at a constant rate, and very little lead-210 at all. However, it seems likely that these assumptions are realistic. Dr Fenton's analyses showed that orange roughy mature at about 32 years of age, when they are about 32 cm in length. Older fish, ranging in size from 38 to 40 cm, were estimated to be 77 years or more. Of those she sampled, the oldest specimen was about 149 years!

The fishing industry didn't know this, or much else, about orange roughy when the first catches were taken in Australian waters. New Zealand boats had found fish spawning in large aggregations, which made for good and easy catches, but Australian boats, although they had found some small aggregations, did not find the first one in our waters in which spawning was occurring — off St Helens on the eastern coast of Tasmania — until 1989.

Spawning aggregations are denser than ordinary schools and are predictable, as the fish spawn at almost the same time every year, presumably responding to some cue in their environment. But how heavily could the St Helens aggregation be fished without long-term damage to the resource? What proportion of the total biomass of fish would the annual catch represent? Could such catches be sustained indefinitely?

To help find out, Dr Tony Smith and Dr Tony Koslow, of the CSIRO Division of Fisheries in Hobart,

Orange roughy is caught off eastern and southern Tasmania.



Tony Rees

Orange roughy eggs.

carried out a survey of the fish off St Helens in July 1990 during an annual spawning aggregation. The fishing ground, centred around an underwater 'hill', had by this time been closed to commercial fishing.

Fisheries biologists have developed various techniques to estimate the biomass of fish stocks, and as nobody knew which would be most suitable for assessing orange roughy spawning aggregations because nobody had ever tried to estimate this species' stocks, the CSIRO team adopted several different approaches.

One involved counting the eggs released. Using a plankton net more than a metre in diameter, lowered to a measured depth and then hauled up vertically, the scientists were able to measure the number of eggs in a known volume of water. This was also useful because for the first time it allowed larvae to be caught, and enabled researchers to record stages in the development of the egg. Of course, relating this to fish numbers relies on knowledge of the average egg production per fish, and of whether a significant proportion of eggs sink to the bottom and escape measurement — factors that are not yet fully established.

The most effective tool was an acoustic sounder, which sends out a sound and detects anything that reflects it. Obviously the sea-bed does, but so too do schools of fish and, with luck and skill, scientists can distinguish their different echoes from the bottom signal. (The particular device used sent out a split beam, producing a stereo effect to improve detection.)

The problem lies in knowing whether the 'marks' that register on the echo-sounder's screen are orange roughy or other species. (Fish do have various 'reflectivities' but the differences are rarely great enough to permit unambiguous identification of a species.) To help solve this, the scientists lowered a camera down through the acoustic marks, taking photographs at known depths. They saw most orange roughy at the bottom, whereas many echoes had been above it. They then put down trawling nets to depths close to the sea-bed where marks had registered. But the nets caught relatively few orange roughy.

Were all the marks other species then? Some were, as the roughy are hunters and feed off smaller fish. But soon it became clear that, as the camera on its mounting came within about 100 metres of a 'mark', whatever comprised the mark started to disperse. To help reveal the nature of the schooled fish, the scientists placed the transducing part of the echo-sounder near a mark but at least 100 m away to avoid scattering the shy fish, and such closeness enabled the acoustic system to resolve individual fish as marks. Many of the fish detected in this way were indeed of orange roughy size, suggesting that they did comprise many of the 'disappearing' marks.

Despite the 15 000 tonnes taken from St Helens Hill by commercial boats before that fishery was closed, it's clear that not everything around the area is orange roughy. Hence, estimating the biomass of the spawning aggregation by echo-sounding is no easy task, and the scientists are still analysing their data, and preparing for further field work this year using the new CSIRO research vessel 'Southern Surveyor'. So far, the best estimate of the biomass in that area is 57 000 tonnes — although the egg-sampling technique suggested a greater abundance — but Dr Koslow stresses that the true figure could lie between half and double this weight.

Cathy Bulman

The fish fetch high prices.

Orange roughy is now our largest 'fish crop', in terms of both monetary value ($50 million in 1989) and tonnes netted. But for such an important fishery it has a woefully small biological data-base. Dr Koslow, in collaboration with Divisional colleague Dr Cathy Bulman, has recently completed research on the diet of roughy in south-eastern Australian waters, in an attempt to make good some of our ignorance of the basic biology of this denizen of the deep.

Tasmanian Department of Sea Fisheries

Bringing in the catch.

The roughy's silver lining

As orange roughy catches have increased massively since 1985, so problems, caused by not knowing what to do with so much fish, have started to emerge.

What we actually eat — in the form of processed fillets — constitutes only 30% of the roughy catch. What can we do with the unwanted parts of millions of expensive fish — dump them? In 1989 in Tasmania, the dumping of waste from the processing of orange roughy caused a public outcry, not least about the environmental problems that it caused. But, according to CSIRO scientists, much of this waste could be put to good use.

Dr Peter Nichols and Dr Jenny Skerratt, of the Division of Oceanography, and Dr Nick Elliott of the Division of Fisheries conducted various chemical analyses of some of the components of the head, swim bladder, frame and skin of roughies used for filleting.

Orange roughy contains a lot of oil — indeed oil comprises about 18% of the fish's weight. Its swim bladder, which gives it buoyancy, is full of a wax ester, whereas many fish have an air-filled bladder. In the tissues, these anomalously active bottom-dwellers do not use triglycerides for their energy storage as do most other vertebrates, but instead more wax esters. Although we cannot digest or absorb these, too much wax can cause diarrhoea. However, we would need to have a very large orange roughy binge to reach that stage!

More importantly, the wax component makes roughy oil a possible substitute for sperm whale oil or jojoba oil. It could be used as an industrial lubricant or in the tanning industry. The scientists believe it could be worth about $1 per kg. From a 10 000-tonne catch could come about 1800 tonnes of oil, representing a windfall of $1·8 million and far less environmental damage.

Fish oil has also been in the news for its importance in human nutrition. The CSIRO scientists found that the useful fatty acids that we can get from fish (called EPA and DHA) were present in much smaller amounts in the oil in the edible flesh of orange roughy compared with that of other commercial Australian fish. That is not to deny that orange roughy is good for you and makes a delicious meal — it simply means that if you are in search of EPA for your heart's sake you won't find much of it there.

The detailed analysis of all the components of roughy 'grease' has enabled the scientists to construct a chemical profile of the fish. Consequently, in future, fish-waste pollution will be more readily tracked and easily identified as originating from roughy. And this unusual fish will be giving us more than just its sweet flesh.

Graeme Johnson

Scientist Jenny Skerratt extracts orange roughy oil.

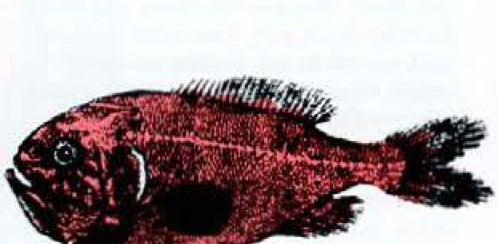
The intrepid researchers examined the stomachs of nearly 7500 fish caught in Australian waters in 1988/89 and found that roughy, with their characteristically large mouths, enjoy a good feed. The juveniles prefer crustaceans, but switch to squid and other fish as they get older and larger.

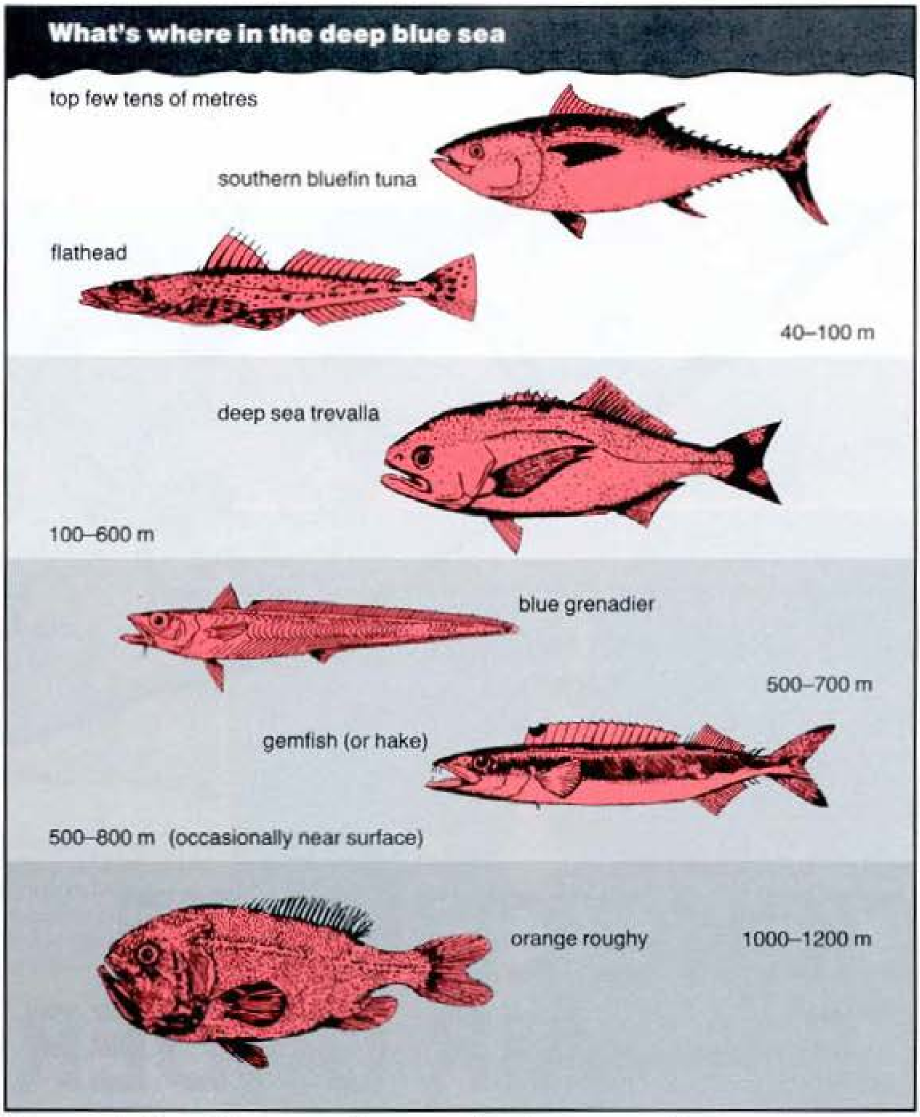
By careful deductions, based on observations of stomach fullness and records for catch-times, the scientists concluded that the fish feed in the afternoon and into the first half of the night. From midnight to midday, they eat a minimum. However, more than half the stomachs examined contained no food, and often those that did have some contained only quite well-digested material. This suggests that the fish start digesting their meals rapidly, emptying their stomachs quickly, but then spend a longish period with an empty stomach while intestinal digestion and absorption proceeds.

Calculations of the weight of food consumed revealed another unusual aspect of roughy. Biologists know that deep-water fish have a low metabolic rate — often ten to a hundred times less than that of surface species. This is partly an adaptation to the fact that food is harder to come by at depth, because light for primary production is non-existent.

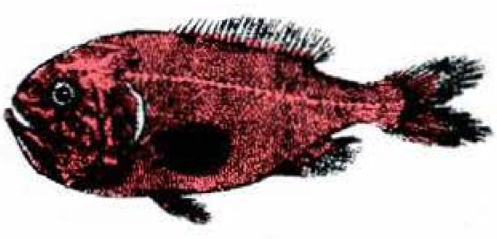
Deep-dwelling fish generally stay still, swimming slowly if at all, and do little. By contrast, Dr Koslow and Dr Bulman concluded from their dietary analyses that orange roughy must have a metabolic rate an order of magnitude greater than other non-migrating fish living at a similar depth. Recent work by other biologists has suggested that roughy, with their well-developed musculature (which makes them good to eat), live in areas with high currents sweeping over the ocean bottom, and have to exert themselves to maintain a position against the current. Hence, they cannot conserve energy by inactivity, like other deep-water fish.

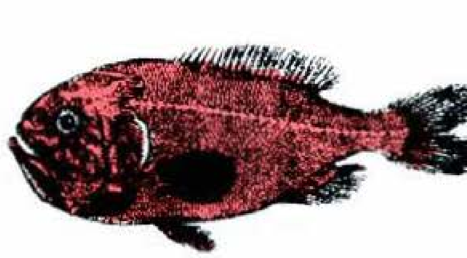
On a proportional basis, they evidently need to eat more than other fish of the deep; consequently abundant





The ocean depths — 1 km or more down — are home to orange roughy.





stocks of roughy can only occur where prey is not limited. It also explains their slow growth rate. If they live in a zone that is relatively poor in food compared with the top 200 m, yet are also active, then they have little energy left over for rapid growth. That is why it takes them 20 years to reach a length of just 30 cm.

Clearly, such slow-growing fish differ greatly from other species caught for human food consumption. Knowledge of other fisheries is inadequate when applied to roughy. It's clear that the fish cannot regenerate their stock as fast as other commercially exploited species. Can the roughy boom continue?

The opinion of the CSIRO scientists is that it cannot. If we wish to have this exceptionally valuable fish available to earn export dollars years from now, then we must reduce the quantity that we are currently netting. Dr Smith believes that, for the east coast Tasmanian stock, the 'total allowable catch' must be reduced from its current 12 000 tonnes (at which it was set without accurate knowledge of stock sizes) to no more than 2700 tonnes. Even if this figure is wrong by a factor of two (which it could be in either direction), clearly we can't continue taking the fish at the level that we have for the last few years, which is bad news for the 54 roughy-fishing boats operating in the area.

Of course, orange roughy exists elsewhere in our territorial waters, including southern Tasmanian waters and the Great Australian Bight. Suffice it to say that only further research and its careful application will enable us to know how much roughy from other sites constitutes a sustainable catch. We should then be able to exploit this new high-quality resource for a long time to come.

Roger Beckmann

More about the topic

Age determination of orange roughy, *Hoplostethus atlanticus* (Pisces, Trachichthyidae) using $^{210}Pb/^{226}Ra$ disequilibria. G.E. Fenton, S.A. Short and D.A. Ritz. *Marine Biology*, 1991, **108** (in press).

St Helens roughy site — 1990 season. J. Lyle. *Australian Fisheries*, 1990, **49** (10), 27–8.

Biomass survey of orange roughy at St Helens. A. Smith and A. Koslow. *Australian Fisheries*, 1990, **49** (10), 29–31.