A TROPHODYNAMIC APPROACH TO THE ECOLOGY OF THE MID-SLOPE COMMUNITY OFF SOUTHEAST AUSTRALIA

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In the late-1980s, a major fishery for orange roughy (*Hoplostethus atlanticus*) developed along the mid-continental slope at depths of 700-1200 m off southeastern Australia. Trawl surveys indicated that the fish community at these depths, which was dominated by orange roughy and an assemblage of oreosomatids and deepwater sharks, was distinct from that found at upper slope depths (400-600 m), where blue grenadier (*Macruronus novaezelandiae*) was the dominant demersal fish (Koslow *et al.* in press; May and Blaber 1989). The trophic ecology of the mid-slope and upper slope fish communities also seemed to differ fundamentally. Along the upper contintental slope, blue grenadier, and their predominant prey, the myctophid *Lampanyctodes hectoris*, migrate daily into near-surface waters, where the myctophid feeds largely on euphausiids. Fish production at upper-slope depths is thus linked to surface plankton production through a simple food chain. However, the dominant components of the mid-slope fish community do not carry out significant diel vertical migrations, so the trophic pathways supporting fish production at these depths are not immediately apparent.

Several hypotheses are proposed to account for the production of orange roughy and other fishes at mid-slope depths: 1) sedimentation from the surface; 2) a 'ladder of vertical migrations' from deep to near-surface waters (Vinogradov and Tseitlin 1983); 3) and advection of material from offshore or downslope. Simple trophodynamic models, similar to those developed by Steele (1974) for the North Sea, were used to evaluate the probable importance of these alternative pathways.

The virgin biomass of the adult orange roughy stock off eastern Tasmania was 10^5 t, based upon acoustic and egg production surveys of the spawning aggregation (Koslow *et al.* 1992). The stock is distributed over an area of approximately 4000 km^2, the area between 700 and 1200 m depth in eastern and southern Tasmania. The daily ration of adult orange roughy is approximately 1% body wt/d, or 5 g $C/m^2 \cdot yr$ (Bulman and Koslow 1992). Primary productivity in the region is 100-200 g $C/m^2 \cdot yr$ (Harris *et al.* 1988; J. Parslow, CSIRO, Hobart, pers. comm.), of which ~5%, or 5-10 g $C/m^2 \cdot yr$, may be estimated to sediment to mid-slope depths (Honjo 1980). Adult orange roughy are generalized predators at the fourth trophic level, feeding on large crustaceans, squid, and fish (Bulman and Koslow 1992). Assuming a 15% ecological efficiency between trophic levels, sedimentation could provide at most only 0.1-0.2 g $C/m^2 \cdot yr$ to this trophic level, or 2-5% of the orange roughy's energetic requirements (Figure 1a).

Surface production in total provides approximately 2.2-4.5 g $C/m^2 \cdot yr$ to the fourth trophic level in the waters off southeastern Australia. If there were efficient vertical transport, such as through extensive vertical migration, *in situ* production could feasibly supply much of the energetic requirements of orange roughy at mid-slope depths (Figure 1b). However, several factors mitigate against this hypothesis. Preliminary data from field studies indicate that the zooplankton and mesopelagic fishes in the region generally do not migrate from mid-slope to near-surface waters on a diel basis, consistent with studies of vertical migration elsewhere (Vinogradov and Tseitlin 1983). There are other predators in the water column at this trophic level, so it is unlikely that more than a small fraction of water-column tertiary production is transported to depths of 700-1200 m. Furthermore, this model assumes a simple phytoplankton -crustacean zooplankton-fish-piscivore food chain. However, phytoplankton grazing in these waters is typically dominated by salps and pyrosomes. These grazers are preyed upon by large fish (e.g. alepocephalids, centrolophids, and several oreosomatids) (Clark *et al.* 1989; C.M. Bulman, CSIRO, Hobart, pers. comm.) not susceptible to predation by orange roughy. Re-working of faecal pellets from the large, thaliacean filter feeders introduces at least one further link into the water column food web (i.e. bacteria and detrital feeders), thereby introducing further metabolic losses. Another indication that orange roughy may be at a somewhat higher trophic level is the fact that a significant proportion of their prey are themselves piscivores. These considerations indicate that local surface production is inadequate to support the orange roughy and other piscivores at mid-slope depths.

These calculations indicate that there is likely a significant flux of energy into the mid-slope community. There are no direct measurements of lateral fluxes in the region. However, current meter moorings off southern and eastern Tasmania indicate there are substantial currents at mid-slope depths (20-30 cm/sec) (V. Lyne, CSIRO, Hobart, pers. comm.). In this region, orange roughy and the dominant oreosomatids are typically aggregated around seamounts, which they may be using to energetic advantage insofar as they provide areas of reduced current. Presumably there is substantial flux of midwater organisms through the region transported by these currents. The mid-slope fish community off southeastern Australia resides in a distinct water mass, Antarctic Intermediate Water, which forms from near-surface waters at 50-55° S latitude in the Southern Ocean and is advected northward into the Atlantic, Pacific, and Indian Ocean basins (Sverdrup *et al.* 1942). The mesopelagic biota residing within this water mass in the Southern Ocean receive significant input from near-surface production through the seasonal vertical migration of dominant sub-Antarctic calanoid copepods at the end of summer to 700-1000 m, where they aestivate through winter. The substantial orange roughy populations that dominate the fish communities along the mid-continental slope around the northern rim of the Southern Ocean may be supported largely by nekton advected past as part of the general northward flow of Antarctic Intermediate Water.

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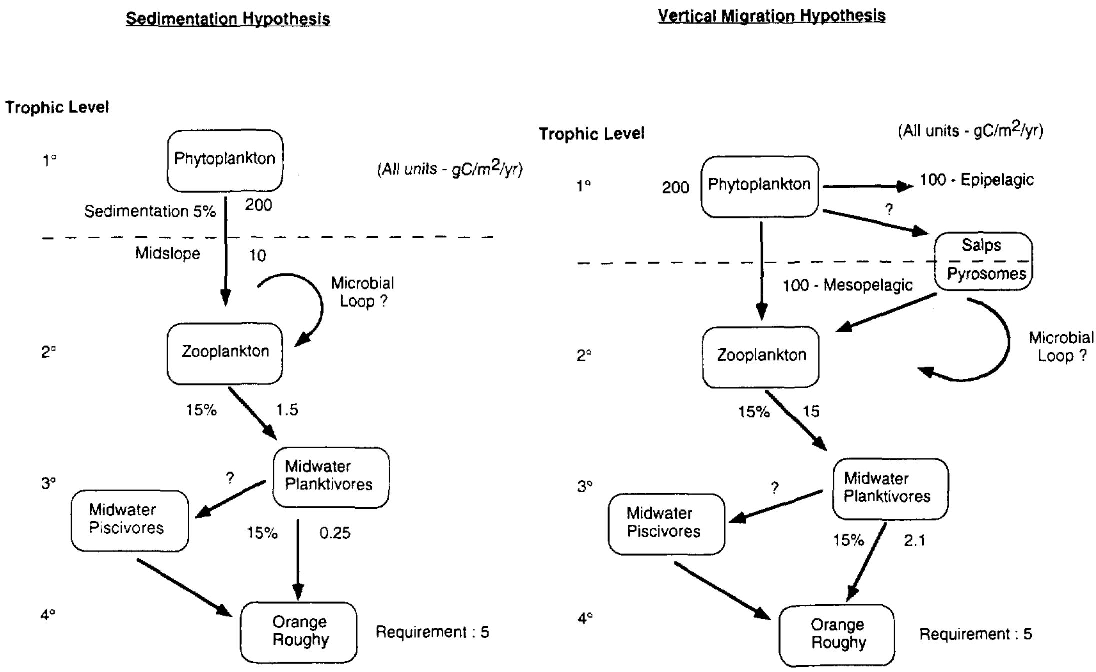

Figure 1. a) Schematic of the sedimentation hypothesis and b) of the vertical migration hypothesis. Both schematics are non-conservative insofar as they neglect the role of midwater piscivores and of a microbial loop in the food web, which would place orange roughy at a higher trophic level. The calculations for the vertical migration hypothesis neglect the role of salps and pyrosomes, which may graze most primary production.