HISTORIC DRIFT BOTTLE EXPERIMENTS SHOW REVERSING SURFACE WATER MASSES IN WESTERN BASS STRAIT WATERS: IMPLICATIONS FOR LOBSTER LARVAL DISPERAL

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Summary

From 1958-1962, 166 batches of 50 weighted drift bottles were released at four stations in western Bass Strait waters to estimate current strength and transport distance of on-shelf waters; 2120 bottles were recovered from 122 batches. Bottles were transported up to 1570 km from release sites at mean speeds of up to 28 cm s⁻¹. The direction of transport showed the presence of seasonally reversing surface waters, which flowed to the west/northwest during summer and to the east/southeast during winter, with some interannual variation in timing of the reversals. Present knowledge of coastal circulation is consistent with drift bottle results. We suggest that larvae of the western population of the rock lobster, Jasus edwardsii, hatching in October in western Bass Strait waters can be transported westerly as far as the eastern Great Australian Bight, and returned to their natal region 9 months later. However, larvae hatching on the west Tasmanian coast may be variously transported offshore, northwards or southeast, before settling in coastal waters.

KEY WORDS: drift bottles; surface water masses; Flinders Current; South Australia Current; Leeuwin Current; Zeehan Current; rock lobster larvae; Jasus edwardsii; phyllosoma transport.

Introduction

The concept of following bodies of water to estimate current strength and direction (termed Langrangian current measurement) has long been a valuable tool in fisheries research because it enables the longitudinal tracking of eggs and larvae of fish, crustaceans and molluscs, and the study of connectivity between biological populations (Tibby 1939; Dodimead & Hollister 1958; Tegner & Butler 1985).

The existence of easterly flowing coastal currents off southern Australia had long been suspected from strandings of tropical species, such as loggerhead turtles, in western Tasmania (Scott & Mollison 1956). Very early studies in Australia used unweighted drift bottles (Russell 1896), but later studies in the 1950s and 1960s used weighted drift bottles to study surface currents (Vaux & Olsen 1961). More modern techniques, including satellite-tracking drifters attached to drogues, satellite imagery, and acoustic Doppler current profilers have now superseded the use of drift bottles (Emery & Thompson 1998; Cresswell 2000). Yet, drift bottles, because they float in the top metre of the water column, measure wave-induced surface drift, whereas modern methods measure deeper oceanic currents, or, in the case of satellite-drifters, currents at the depth of the attached drogue, usually 10-20 m. If larvae spend time in surface waters, then data from drift bottle transport are relevant for studies of larval advection, and may help resolve uncertainties about larval longevity and connectedness between sub-populations (Tegner & Butler 1985; Harding & Trites 1988; Hare 2005).

The southern rock lobster, Jasus edwardsii (Hutton), is the basis of major fisheries in SE Australia and New Zealand. The larval stages of this lobster are remarkable in that they involve 11 phyllosome developmental stages (Lesser 1978; Booth & Phillips 1994). The last stage (stage 11) metamorphoses into the puerulus stage in inner shelf waters, and then migrates further inshore to settle in shallow coastal waters (Lewis 1981; Booth et al. 1991), and moults to a benthic juvenile within 10-20 days (Booth 2001; Kittaka et al. 2005). The duration of the phyllosome stages is still controversial. In culture the larvae can be reared through to settlement in 9 months at 18 °C (Kittaka 1994), but in the ocean the time to settlement has been variously suggested as 9-13 months (Booth 1989), 12-24 months (Booth 1994), and 17-18 months (Bruce et al. 2000).
In this paper drift bottle data from weighted and unweighted bottles, collected by the first author from 1958-1962 in SE Australian waters (CSIRO 1968), are analysed for the first time, and compared with present knowledge of oceanographic and coastal currents of the region. The implications of current flow rates of surface waters, as found by these experiments, are discussed in the context of the likely dispersal and duration of the larval stages of the western population of the lobster in SE Australian waters.

**Materials and Methods**

Batches of fifty 750 ml sealed long-necked drift bottles, ballasted with crushed dolerite rock so as to float upright ~5 cm above the sea surface, and containing a questionnaire and return address cards, were released monthly from ships at four stations during the period 1958-1962 (Table 1). The questionnaire sought the location and time of stranding, and also whether any living organisms were attached to the bottle, as such information was indicative of a very recent stranding. Four release stations (Table 1; Fig. 1) were chosen because they were in the core region of the distribution of western populations of the southern rock lobster, and would likely indicate the extent of larval dispersal. In January to November 1960 11 batches of 50 unweighted drift bottles, one each month, were released contemporaneously with 50 weighted bottles from Station 2 to compare transport differences between the two types of bottle.

![Map of south-eastern Australia](image)

**Figure 1.** Map of south-eastern Australia, and in inset southern Australia, showing: (with arrows) direction of flow of the major oceanographic currents in summer, and (in bold) four release stations 1-4. Locations of coastal strandings of drift bottles, also numbered 1-4 according to the station where they were released, are shown with small numbers. Summer releases were mainly from November to May when drift bottles drifted generally to NW - N. EAC is East Australia Current.

**Results**

Drift bottles were often recovered over a period of a few days to months after release, depending on the remoteness of the site of stranding. The most reliable indicators of drift speed were the recovery data with the shortest periods of drift. In addition, the presence of attached living organisms on a stranded bottle was indicative of a very recent stranding. We used these criteria to select a fraction of the returns for each month showing the fastest rates of drift for analysis and presentation. A
summary of the period, distance and direction of drift, mean drift speed, and location of stranding for these bottles is given in Table 1. In this table the monthly release batches of bottles are grouped in each year according to the general direction of drift.

The drift bottle recoveries indicated seasonally reversing surface water masses in directions that followed the trend of the coast or shelf edge (Figs 1, 2). In winter the surface flow was easterly through Bass Strait at Stations 1 and 2, and to the SE at Stations 3 and 4, reversing in summer to W - NW at Stations 1 and 2, and NE - NW at Stations 3 and 4. The time of the reversals varied interannually. At Stations 1 and 2 the flow changed from westerly to easterly in March to April, and reverted to westerly in September to November; however, during October to February some variability occurred in the direction of drift, when brief reversals occurred (Fig. 1). At Stations 3 and 4 the summer northerly flows were more sporadic. Some 76% of release batches of drift bottles were transported to the southeast in most months of the year, while the remaining 24% of batches were transported northwards. In some cases drift bottles were caught in flows to the NE through Bass Strait, to be stranded on beaches of eastern Victoria to SE Queensland. No bottles were ever recovered on the northern Tasmanian coast.

The strength of flow of the surface water masses can be inferred from the fastest transport rates recorded. At Stations 1 and 2 the fastest mean monthly drift speeds were 10.7-11.1 cm s⁻¹ (to W-NW), and 14.6-19.1 cm s⁻¹ (to E), whereas at the Tasmanian Stations 3 and 4 the fastest mean drift rates were 4.7-5.4 cm s⁻¹ (to N-NW), and 9.0-10.3 cm s⁻¹ (to SE). The differences between stations may reflect true differences in speed, or alternatively may be an artefact of the sparser human habitations on the west and south Tasmanian coasts compared with mainland coasts, and the lower probability of finding bottles early after stranding.

A comparison of data for the 11 months in which unweighted and weighted bottles were released simultaneously from Station 2 is summarised in Table 2. Unweighted bottles tended to drift for a longer time, a greater distance, and at a faster speed. However, none of the differences were significant (t = 0.4-1.9; ns) due to the high variability in the data. We then examined the data for the three winter months of June to August 1960. The mean distance travelled by weighted bottles was
197.7 km (s.e. 29.8) and by unweighted bottles was 1219.8 km (s.e. 119.8), many of which stranded on the Queensland coast (and omitting the datum for an unweighted bottle recovered off Papua > 3 years later). The difference was highly significant (N = 79; t = 6.4; P<0.001).

**Table 1.** Months and years of release and total number of bottles released (in batches of 50) for which there were recoveries at four stations from 1958-1962, with data on N, the number of bottles used for the analysis, with their time (in days) at liberty, distance covered (km), range in mean drift speed (cm s⁻¹), direction of drift, and stranding regions. Coastal stranding regions are indicated by compass directions eg SW Vic. = south western Victoria ; C=Central; EP=Eyre Peninsula; FI = Flinders I., Tas.; KI (Tas.) = King I., in Bass Strait, and KI (SA) = Kangaroo I. South Australia. YP = Yorke Peninsula, South Australia.

| Release months | Number released (recovered) | N  | Range in Distance (km) | Range in Time at liberty (days) | Drift Speed Range (cm s⁻¹) | Direction of drift | Stranding regions               |
|----------------|-----------------------------|----|------------------------|--------------------------------|---------------------------|-------------------|--------------------------------|
| **Station 1; 15 km south of Cape Northumberland, SA. (Lat. 38° 12’ S. Long. 140° 40’ E.)** | | | | | | | |
| 9, 10, 12: 1958 | 150 (95) | 9 | 17 – 400 | 1 – 50 | 2.8 - 19.3 | E | SW Vic. |
| 11:1958 | 50 (40) | 6 | 96 | 24 | 2.6 | NW | SE SA |
| 1-2: 1959 | 100 (20) | 2 | 378 – 587 | 37 – 49 | 11.6-13.9 | NW | SE –EP, SA |
| 3-8: 1959 | 300 (100) | 12 | 72 – 880 | 7 – 75 | 5.2 -13.5 | E | SW Vic.; SE NSW |
| 9,11:1959 | 100 (61) | 15 | 80 – 226 | 13 – 35 | 7.1 -10.1 | NW | SE SA |
| 10,12:1959 | 100 (91) | 45 | 17 – 161 | 3 – 11 | 6.4 -16.9 | E | SE SA; SW Vic. |
| 1,4 – 8:1960 | 300 (137) | 41 | 15 – 293 | 2 – 40 | 7.9 -27.8 | E | SE SA – SW Vic. |
| 9,12; 1960 | 100 (32) | 4 | 148 – 370 | 26 – 56 | 6.6 -8.3 | NW | SE SA; N KI, SA |
| 10,11; 1960 | 100 (66) | 33 | 124 – 150 | 8 – 13 | 12.1-18.0 | E | SW Vic. |
| **Station 2; 56 km SW of Cape Otway, Victoria (Lat. 39° 15’ S. Long. 143° 5’ E.).** | | | | | | | |
| 9,10; 1958 | 100 (34) | 2 | 282 | 32 – 36 | 9.0 -10.3 | E | E Vic. |
| 11,‘58-1,’59 | 150 (58) | 6 | 59 – 283 | 10 – 30 | 6.8 -16.3 | W | SW Vic. – SE SA |
| 3-9; 1959 | 250 (62) | 6 | 191 – 809 | 27 – 67 | 5.8 -13.9 | E | KI., Tas. SW Vic. - .SE NSW |
| 10,11; 1959 | 150 (50) | 3 | 161 – 294 | 21 – 43 | 7.9 -8.8 | W | SW Vic., SE SA |
| 12,’59-1,’60 | 100 (51) | 5 | 148 – 348 | 23 – 27 | 6.4 -17.5 | E | Central Vic. |
| 2,3; 1960 | 100 (34) | 2 | 126 – 224 | 19 – 54 | 4.7 -17.7 | W | SW Vic. |
| 4 –10; 1960 | 350 (132) | 40 | 85 – 500 | 6 – 190 | 3.0 –31.9 | E | FI, Tas., SW-C Vic. |
| 11; 1960 | 50 (3) | 1 | 391 | 46 | 9.8 | W | SE SA |
| 3-9; 1961 | 300 (102) | 6 | 67 – 420 | 9 – 115 | 4.3 -15.6 | E | K I., Tas., C-E Vic. |
| 10,11; 1961 | 100 (37) | 4 | 124 – 224 | 16 – 32 | 4.5 -16.3 | W | SW Vic. |
| 10,12: 1961 | 50 (40) | 6 | 133 – 282 | 23 – 36 | 6.6 -19.0 | E | C-E Vic. |
| 1,3; 1962 | 100 (60) | 3 | 122 – 246 | 15 – 35 | 8.1 -9.4 | W | SW Vic., SE SA |
| 2; 1962 | 50 (3) | 1 | 96 | 30 | 3.6 | E | K I., Tas. |
| **Station 3; abeam of West Point, Tasmania (Lat. 41° 3’ S. Long. 144° 23’ E.)** | | | | | | | |
| 9: 1958 | 50 (10) | 1 | 139 | 29 | 5.6 | SE | SW Tas. |
| 11,12: 1958 | 100 (39) | 3 | 772 – 1036 | 99 - 163 | 7.3 - 9.0 | NW | Enc.Bay -EP, SA |
| 1: 1959 | 50 (23) | 1 | 363 | 56 | 7.5 | N | W Vic. |
HISTORIC DRIFT BOTTLE EXPERIMENTS IN SE AUSTRALIAN WATERS

| Station | Year | Bottle Size | Time Period (days) | Distance (km) | Mean Speed (cm s⁻¹) |
|---------|------|-------------|-------------------|--------------|-------------------|
| 2: 1959 | 50 (13) | 1 | 24 | 15 | 1.9 | E W Tas. |
| 3-12: 1959 | 450 (130) | 94 | 32 – 289 | 13 - 44 | 1.5 – 9.0 | SE SW Tas. |
| 2-4: 1960 | 150 (35) | 13 | 26 – 148 | 4 – 16 | 4.9 – 10.7 | SE SW Tas. |
| 5: 1960 | 50 (1) | 1 | 601 | 237 | 3.0 | NW E Vic. |
| 6-11: 1960 | 250 (50) | 17 | 7 – 204 | 19 - 86 | 0.4 – 10.3 | SE SW Tas. |
| 12: 1960 | 50 (3) | 1 | 113 | 114 | 1.1 | N NW Tas. |
| 2,4,7: 1961 | 150 (17) | 5 | 63 – 352 | 5 - 119 | 3.4 – 21 | SE SW-S Tas. |
| 7: 1961 | 50 (1) | 1 | 622 | 208 | 3.4 | NW KI, SA |
| 9: 1961 | 50 (4) | 1 | 244 | 65 | 4.3 | NE FI. Tas. |
| 1,3: 1962 | 100 (17) | 2 | 41 – 113 | 5 - 17 | 7.7 – 9.4 | NE E. Vic. |
| 2,4,5: 1962 | 150 (14) | 4 | 24 – 96 | 6 - 65 | 1.7 – 4.7 | SE SW Tas. |

Station 4; abeam of Mount Heemskirk Station (Lat. 41° 56´ S. Long. 145° 1´ E.).

| Station | Year | Bottle Size | Time Period (days) | Distance (km) | Mean Speed (cm s⁻¹) |
|---------|------|-------------|-------------------|--------------|-------------------|
| 9: 1958 | 50 (13) | 1 | 28 | 93 | 0.4 | N W Tas. |
| 11: 1958 | 50 (3) | 2 | 100 – 253 | 11-31 | 9.4 –10.5 | SE SW Tas. |
| 11: 1958 | 50 (21) | 2 | 566–1043 | 68-267 | 4.5 – 9.6 | NW YP, SE SA |
| 1,2,4: 1959 | 150 (72) | 6 | 30 – 81 | 9-17 | 3.0 – 5.6 | SE SW Tas. |
| 3,6: 1959 | 100 (36) | 2 | 20 – 28 | 17-45 | 0.4 – 1.9 | NE W Tas. |
| 5,9,10: 1959 | 150 (48) | 9 | 30 – 81 | 12-32 | 1.1 – 5.6 | SE SW Tas. |
| 2-4: 1960 | 150 (81) | 50 | 30 – 120 | 3-21 | 1.7 –27.8 | SE SW Tas. |
| 5: 1960 | 50 (2) | 2 | 335–1721 | 79-307 | 5.6 – 6.4 | NE FI, Tas. SE Qld |
| 6-11: 1960 | 250 (23) | 13 | 44 – 178 | 20-853 | 0.2 –10.3 | SE SW Tas. |
| 1,2,8,10: 1961 | 200 (46) | 11 | 13 – 180 | 2-105 | 1.9 – 7.5 | SE SW Tas. |
| 11,12: 1961 | 100 (58) | 23 | 15 – 20 | 16-46 | 0.4 – 1.1 | E W Tas. |
| 1: 1962 | 50 (4) | 1 | 117 | 32 | 4.2 | SE SW Tas. |
| 3: 1962 | 50 (48) | 1 | 30 | 29 | 1.3 | E W Tas. |

Discussion

When this drift bottle study began in 1958, the coastal currents of SE Australia were virtually unknown, and this study was the first to establish seasonally reversing water mass flows. Since then studies by Gibbs et al. (1986) and Rochford (1986), reviews by Church & Craig (1998), Cresswell (2000), Rintoul (2000) and McClatchie & Ward (2006), and numerical modelling by Middleton & Cirano (2002), Middleton & Platov (2003), and Cirano & Middleton (2004) have shed much light on the oceanic and coastal circulation of the region. The shelf width varies from 20-30 km off western Tasmania to >200 km off Eyre Peninsula, South Australia, while depths in Bass Strait are 60-70 m. Two currents influence the region’s oceanography.

Table 2. A comparison of mean period at liberty (days), mean distance travelled (km), and mean drift speed (km day⁻¹) for weighted and unweighted bottles released in January-November 1960 at Station 2. Standard errors in brackets.

| Time period (days) | Distance (km) | Mean speed (cm s⁻¹) |
|--------------------|---------------|---------------------|
| **Weighted**       | 52.1 (15.6)   | 217.4 (38.0)        | 8.7 (2.3)       |
| **Unweighted**     | 65.5 (25.6)   | 334.8 (88.3)        | 11.9 (2.0)      |
1. The Flinders Current, a deep western flowing northern boundary current (Bye 1972, Middleton & Cirano 2002), averaging 5 cm s\(^{-1}\) (maximum 25 cm s\(^{-1}\)), originates south of western Victoria and flows NW toward the Great Australian Bight and then west. The current is adjacent to the continental slope, and extends from the surface to 1800 m depth, but is intimately related to flows on the adjoining shelf (Bye 1983). Near the coast, the summer, wind-induced Ekman transport induces upwelling plumes, and leads to westerly coastal currents of up to 10 cm s\(^{-1}\), which are independent of the Flinders Current (Bye 1972; Middleton & Platov 2003). Upwelling plumes are strongest on the narrow SE shelf of South Australia and weaken toward the west off western Kangaroo I. and Eyre Peninsula (McClatchie & Ward 2005). The inshore currents are seasonal and driven by the prevailing SE winds, but the deeper Flinders Current apparently persists in winter with a much weaker flow, measured at 4 cm s\(^{-1}\) off western Tasmania at 995 m depth (Cirano & Middleton 2004). The waters off South Australia are well stratified in summer, with temperatures of 16-19 °C near the surface and 12-13 °C at 100 m.

2. A winter shelf current flows eastward from Cape Leeuwin, W.A. to southern Tasmania. In the west, the current, termed the Leeuwin Current, originating from NW Australia (Cresswell 1991), flows around Cape Leeuwin and then east into the Great Australian Bight, where at about 130°E it is absorbed into the waters of the west wind drift (Rochford 1986). Further east off central South Australia, a current, variously called the South Australia Current or the Coastal Current, is driven by zonal winds and pressure gradients with mean longshore speeds of 15-30 cm s\(^{-1}\) (Rochford 1986; Cirano & Middleton 2004). A gravity current flows out of Spencer Gulf in March-May each year and turns SE (Lennon et al. 1987; Nunes Vaz et al. 1990). Off the west coast of Tasmania the Zeehan Current (Cresswell 2000), flows year round to the south on the outer continental shelf at average speeds of ~30 cm.s\(^{-1}\). The current is strongest in winter at 200 m depth, but weak and meandering closer to shore at 100 m depth in summer, where current meter readings showed frequent brief reversals from July to February, possibly associated with local winds (Cresswell 2000).

3. In the shallower Bass Strait, the currents are driven by a combination of the West Wind Drift, local winds, the winter coastal current, and coastal trapped waves (Cirano & Middleton 2004). In winter, currents are easterly at speeds of ~ 4 cm s\(^{-1}\) and the North Bass Strait water mass flows to the east and northeast, cascading into the Tasman Sea (Newell 1961, Rochford 1975, Gibbs et al. 1986). A NE-ward jet off NW Tasmania at 11 cm s\(^{-1}\), driven by the West Wind Drift system, enters Bass Strait south of King I. and contributes to the flow eastward. In summer, water from the East Australia Current penetrates the Strait from the east, and the flows are westerly (Newell 1961; Rochford 1975). Jones (1980) found that in NE Bass Strait the wind induced an upper layer surface flow of about 2% of the wind speed.

Drift bottle movements and speeds are in remarkably close agreement with present knowledge of these regional currents. The 19 batches of bottles from Stations 1 and 2, which went NW in summer, were taken in surface currents at comparable speeds recorded for the Flinders Current (10 cm s\(^{-1}\)). The 40 batches, which went east in winter were evidently taken by surface currents at about the same speed as the South Australia Current (15-20 cm s\(^{-1}\)). Transport through Bass Strait was presumably assisted by westerly winds due to the low mean residual flow rate eastwards of the mid-Bass Strait water mass (Rochford 1986).

The direction of transport of drift bottles from the two Tasmanian stations is also consistent with knowledge of the variable Zeehan Current and the NE-ward jet into Bass Strait. Of the minority (24%) of batches transported north, 74% of them occurred during November to May when the Zeehan Current is weak or meandering, and subject to reversals of flow.

The non-significant tendency of unweighted bottles to drift further and at greater speed was largely due to the noisiness of the data. However, the large differences in drift distances during winter, when the unweighted bottles stranded far up the east coast of NSW and Queensland, suggest a
strong inshore northward-flowing surface counter-current. A similar result was shown by Russell (1896), also with unweighted bottles.

There is supplementary evidence from the outflow of higher density water from Spencer Gulf, naturally labelled with higher levels of mercury, that the reversal of flow extends to 250 - 300 m depth. In early winter (March to May) this lens of water flowed into the De Couedic Canyon off Spencer Gulf onto the shelf slope, and then SE toward Bass Strait (Newell 1961; Kitani 1977; Olsen 1983; Nunes Vaz 1990).

The main value of the drift bottle data is the evidence it provides about possible transport distances of lobster larvae. During the pelagic phyllosome stages, larvae undertake a diurnal migration to the surface at night (Olsen 1966; Booth & Stewart 1992; Booth 1994). Bruce et al. (2000) found that phyllosome larvae were mostly confined to the upper 100 m of the water column, and were commonly at the surface at night. Early stage phyllosome larvae were found mainly in on-shelf waters, whereas late-stage phyllosome larvae were equally abundant off the shelf (Bruce et al. 2000). Phyllosome larvae have a limited capacity to swim horizontally for a few tens of km, depending on lipid reserves (Jeffs et al. 2001). Hence larvae are mainly transported passively by surface water movement and/or ocean currents, supplemented by two behavioural mechanisms. These are the ability to control their depth in the water column and so take advantage of surface currents (eg Olsen 1966; Phillips & McWilliams 1986), and the ability to delay metamorphosis (Booth 1994).

Each year in the SE of SA and northern Tasmania, the hatching of larvae of western populations of lobster occurs in October – November, and settlement of pueruli occurs mainly in July-August after a presumptive larval stage of ~9 months (Lewis 1977). In west Tasmania the abundance of the earliest phyllosome stage peaks in October (range September – February) (Bruce et al. 2000), and settlement of pueruli occurs throughout most of the year with peaks in December-January and August-September (Gardner et al. 1998). From data on coincidence of puerulus settlement and the Subtropical Front (the boundary between tropical and Southern Ocean waters) and satellite drifter data (Cresswell 2000), Bruce et al. (2000) inferred that the summer settlement peak occurred after 15-16 months, and the winter peak after 22-23 months. On the basis of the drift bottle data analysed here, Lewis (1977) suggested that lobster larvae hatching in the coastal regions near Stations 1 and 2 were transported west to NW in surface waters for ~5 months, and returned with the reverse flow for ~ 4 months. At a mean rate of 10 cm s\(^{-1}\) to the NW, as shown by drift bottle speeds (eg Table 1; Feb. 1959, Dec. 1960), larvae in surface waters could notionally be advected 1300 km to the NW, and, in the reverse flow, at a faster mean speed of 15 cm s\(^{-1}\) (Table 1), they could be transported ~1500 km to the SE to natal habitats.

The potential transport of larvae hatching in early summer on the west Tasmanian coast is more variable. From spring to autumn the Zeehan Current is weak and meandering, and larvae could be transported passively in surface waters or ocean currents (a) NW to the central South Australian coast, (b) NE into Bass Strait, (c) SE and east toward Bruny I. and Maria I., Tasmania, as variously occurred with some drift bottles, or (d) retained in eddies on the west Tasmanian coast (Bruce et al. 2000; Cresswell 2000). Larvae transported NW could be returned to Tasmanian waters in the reversing current some 9 months later, evidence for which was adduced by Bruce et al. (2000). However, the above calculations do not allow for the possible presence of coastal retention zones in nearshore boundary layers (reviewed by Largier 2004), where larvae may be retained for shorter or longer periods, as suggested above for the west Tasmanian coast. Given the complexity of oceanographic and coastal currents off SE Australia, lobster larvae must inevitably be transported between sub-populations of adults. This factor, and the extensive movement of some adults (Linnane et al. 2005), together account for the genetic homogeneity of the western population of the lobster in South Australia and western Tasmania (Ovenden & Brasher 1994).

Summer sea temperatures are ~5 °C higher in South Australian waters than in Tasmanian waters, and Bruce et al. (2000) presented evidence that phyllosome larvae develop faster in the more
northern waters consistent with laboratory findings (Kittaka 1994). The reversing surface currents, first shown by drift bottle experiments and confirmed by recent oceanographic studies, lend strong support to the hypothesis of Lewis (1977) that the pelagic larval stage for lobster larvae is ~9 months in South Australian and western Victorian waters, in contrast to the much longer pelagic larval stages suggested by Bruce et al. (2000) for the colder waters of Tasmania.

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