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行政院農業委員會水產試驗所107年度科技計畫研究報告

計畫名稱：　臺灣周邊海域漁場環境監測IV-(4/4) (第4年/全程4年)

(英文名稱)　Environmental monitoring of fishing grounds in the coastal and offshore waters around Taiwan IV-(4/4)

計畫編號：　107農科-9.2.2-水-A1(4)

全程計畫期間：　自 104年1月1日 至 107年12月31日
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1072810

一、執行成果中文摘要：

本(107)年度完成冬、春、夏季漁場環境調查3航次(107/01/22～107/02/02；107/04/17～107/05/18；107/08/03～107/08/26)，完成周邊海域166個站次之CTD投放、分層採水、營養鹽類、葉綠素甲、浮游動物及仔稚魚等樣本採集作業，秋季調查航次尚待天候許可後執行；未來測站4位置將由122˚30'調整至122˚29'「暫訂執法線」西側之我國海域，其餘測站不變動。本年度冬季大陸沿岸冷水的位置與往年相較屬偏北之分布，冬季表層水溫介於16.17~25.97℃，鹽度介於32.19~34.70psu，硝酸鹽介於0.4~5.9μM，磷酸鹽介於0.017~0.272μM，矽酸鹽介於0.3~3.8μM，葉綠素濃度介於0.022~1.657 mg/m^3，浮游動物豐度介於16.35~299.7 inds./m^3；春季採樣時間較晚，已經接近夏季型態，海峽由黑潮支流及南海表層水佔據，表水溫介於20.71~29.56℃，鹽度介於33.72~34.78psu，硝酸鹽介於0.1~2.5μM，磷酸鹽介於0~0.502μM，矽酸鹽介於0.6~12.3μM，葉綠素濃度介於0.01~1.14 mg/m^3，浮游動物豐度介於6.74~201.3 inds./m^3。夏季整個台灣周邊海域水溫均高，鹽度則是因為夏季降雨量高河川淡水輸入較多，在較近岸測站有低鹽水出現。表水溫介於25.06~30.78℃，鹽度介於31.35~34.35psu。本年度利用本計畫2007-2013年長期觀測資料，探討臺灣海峽冬季仔稚魚群聚分布特徵與水團及鋒面間之關係，對於臺灣海峽冬季仔稚魚群聚之長期動態及與環境變動之關係提供了深入的探討。本年度編撰印製2016年及2017年《臺灣周邊海域漁場環境監測航次報告》共2冊，內容涵蓋計畫執行之海上採樣作業流程、各調查項目實驗室檢測流程，並刊出周邊海域漁場環境調查成果供各界參考，並將歷年周邊海域調查資料上傳環保署環境資源資料交換平台(CDX)、政府資料交換平台(OpenData)、內政部地理圖資雲(TGOS)、農委會公務統計系統及水試所全球資訊網網頁，達成促進資料之流通加值應用之目的。

二、執行成果英文摘要：

Three cruises were conducted in February, April and August during 2018 to collect temperature, salinity, nutrients, chlorophyll-a, zooplankton and fish larvae in the surrounding waters off Taiwan. A total of 166 stations were investigated. The autumn cruise will be conducted as long as the weather permitted. In the future, station 4 will be adjusted westward from 122˚30' N to 122˚29' N. In winter, the distribution of cold China Coastal Current retreated to the north of the Taiwan Strait. Sea surface temperature (SST), salinity, nitrate, phosphate, silicate, and chlorophyll-a and zooplankton abundance in winter were 16.17~25.97 ℃, 32.19~34.70 psu, 0.4~5.9 μM, 0.017~0.272 μM, 0.3~3.8 μM, 0.022~1.657 mg/m^3 and 16.35~299.7 ind./m^3, respectively. In spring, the flow pattern in the surrounding waters of Taiwan was mainly influenced by Kuroshio Current and Southern China Sea Surface Water. SST, salinity, nitrate, phosphate, silicate, and chlorophyll-a and zooplankton abundance in spring were 20.71~29.56 ℃, 33.72~34.78psu, 0.1~2.5μM, 0~0.502μM, 0.6~12.3μM, 0.01~1.14mg/m^3 and 6.74~201.3 ind./m^3, respectively. In summer, SST and SSS were 25.06~30.78 ℃ and 31.35~34.35psu, respectively. This study demonstrated the interannual variations of larval fish assemblages associated with ocean fronts in the Taiwan Strait (TS), based on seven consecutive cruises in winter from 2007 to 2013, which provides crucial information about the status of the larval fish community and presents a better understanding of the long-term dynamics and the influence of environmental fluctuations in the TS during winter. Besides, we published the "Cruise Report of TaiCOFI Surveys" in 2016 and 2017 to provide our investigation results to the public. Standard procedures of field program and sample analysis are described in detail and the distribution of water temperature, salinity, nutrients, chlorophyll- a , zooplankton and primary production are illustrated in figures for each cruise. The historical investigation data were uploaded to the domestic data-sharing panel, such as CDX, OpenData, TGOS, COA statistics system and TFRI website. In this way, the data of this project can be used for scholarly research available to other investigators.

三、計畫目的：

1. 按季執行水溫、鹽度、營養鹽類、葉綠素甲、浮游動物及仔稚魚採集 ，完成各項實驗分析。
2. 持續充實臺灣周邊海域漁場環境監測資料庫，定期出版航次報告供各 界參考使用。
3. 探討水文環境變動對臺灣周邊海域經濟性魚類仔稚魚分布之影響。

四、重要工作項目及實施方法：

(一)樣本採集

利用水試一號船按季至臺灣周邊海域各測站，以Seabird 9-11 Plus溫鹽深儀(CTD)投放至1000m (水深不足測站離底5m)以取得溫深鹽之連續資料，並利用輪 盤採水系統採集5、25、50、75、100、150m等水層之水樣，攜回實驗室測定營 養鹽類以及葉綠素甲濃度。並以ORI網下放至200m深(水深不足測站離底5m)，以 1m/s速度上揚採集浮游動物樣本。

(二)實驗分析

分別利用鎘銅還原-偶氮法 (pink azo dye)、偶氮法、鉬酸藍 法 (molybdenum blue method)及矽酸藍法 (silicon molybdenum blue method)，以分光光度 計測定吸光值後換算硝酸、亞硝酸、磷酸、矽酸之濃度。濾畢各層海水之濾紙 以丙酮溶

1072810

解萃取，以Trichromatic法測量葉綠素甲濃度。浮游動物樣本於測量 生物沉澱量、排水容積、濕重，進行30大類以及仔稚魚鑑定。

(三)資料處理

計算種類豐富度指數(D)(Margalef's index of species richness)及物種歧異度指數(H)(Shannon-Wiener's index of species diversity)等指標，進行群聚分析(Cluster analysis)探討各測站及海域間仔稚魚的群聚變異，並以相關分析(Pearson correlation analysis)及泛加成模式(Generalized additive model)等統計方法，探討仔稚魚豐度變化與海洋環境因子間的關係。

五、結果與討論：

本研究利用臺灣周邊海域漁場環境監測計畫2007-2013年長期觀測資料，探討臺灣海峽冬季仔稚魚群聚分布特徵與水團及鋒面間之關係。冬季東北季風盛行期間，低溫低鹽之大陸沿岸水入侵臺灣海峽，形成的大陸沿岸水混合水與黑潮支流形成鋒面，北部海域亦可發現明顯的溫度梯度變化，於北部海域則與黑潮水交會，在這兩個區域形成明顯的鋒面，其位置隨冷水勢力強弱而存在年間差異，冷水勢力以2008年最弱，2012年最強，水文環境與仔至魚群聚亦隨之變動。環境因子及仔稚魚豐度之分布亦隨之變動。群聚分析結果顯示冬季台灣海峽各年度仔稚魚群聚大致可分為黑潮群(KC)及大陸沿岸水混合水群(MCCW)，群聚分布與鋒面位置大略吻合。 黑潮群中常見的優勢種多是由中層魚類所組成，年間變化較小，包括了七星底燈魚 *Benthosema pterotum* 、眶燈魚屬 *Diaphus* B等，在各年度都是主要的組成種類，在個航次間的出現率為100%，海鰗鰍 *Bregmaceros* spp.則達71.4%。大陸沿岸水群中較常見的優勢種為底棲性種類，優勢種類多，鮋科Scorpaenidae spp.、蝦虎科Gobiidae spp.，出現頻率達57.1%。此外，海鰗鰍 *Bregmaceros* spp.及帶魚 *Trichiurus* spp.在各水團都會出現，亦為常見優勢種。相較之下，黑潮群的優勢種類組成較穩定，年間變化較小，大陸沿岸水群優勢種種類較多，年間組成變化大。BIO-ENV分析顯示，仔稚魚群聚分布形式與環境因子分布形式，兩者有著中度的相關性，而這些因子的組成中，以溫度、鹽度為主要的因子。也就是說，臺灣海峽冬季仔稚魚群聚分布形式，主要受海域的溫鹽影響。黑潮是屬相對水溫等性質較為穩定的大洋性水團，因此適應於此環境的仔稚魚種類會較為豐富，仔稚魚組成兼具了高多樣性與高均勻度；而大陸沿岸水團水溫低且受到黑潮支流及南海表層水交互作用的影響，水文狀態較為複雜且變化較劇烈，因此只有少數適應性較強的物種可以生存，且由於不同水團間的鋒面區富含營養鹽，造成某物種大量出現，以致歧異度降低，均勻度亦較低。本研究對於台灣海峽冬季仔稚魚群聚之長期動態及與環境變動之關係提供了深入的探討。

六、結論：

冬季東北季風盛行期間，大陸沿岸水入侵臺灣海峽與黑潮支流形成鋒面，位置存在年間差異，環境因子及仔稚魚豐度之分布亦隨之變動。臺灣海峽仔稚魚群聚大致可分為黑潮群及大陸沿岸水群，群聚分布與鋒面位置大略吻合，鋒面兩側仔魚豐度有明顯差異；鋒面對黑潮群仔稚魚形成明顯分佈界線，而沿岸水群中的底棲性魚類分布則較不受鋒面影響。在分布上，眶燈魚與海鰗鰍為冬季黑潮最具代表性的物種，在站間分布最均勻；沿岸水群之主要貢獻物種年間變化大，日本鯷、鮋科、帶魚較具代表性。在數量上，冬季黑潮群優勢種多是由中層魚類所組成，組成較穩定，七星底燈魚、眶燈魚、海鰗鰍、帶魚為最常見的類別；沿岸水群常見的優勢種多是由底棲魚類所組成，年間組成變化大，蝦虎、鮋科、七星底燈魚較具代表性。臺灣海峽冬季仔稚魚群聚分布，主要受水溫及鹽度分布形式影響，兩者有著中度的相關性。

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1072810

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1072810

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臺灣海峽冬季仔稚魚群聚組成及分布與水團鋒面間關係之年間變異

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研究人員：陳郁凱、潘佳怡、曾秀茹、蘇博堃
執行單位：海洋漁業組

中文摘要

本研究利用臺灣周邊海域漁場環境監測計畫 2007-2013 年長期觀測資料，探討臺灣海峽冬季仔稚魚群聚分布特徵與水團及鋒面間之關係。冬季東北季風盛行期間，低溫低鹽之大陸沿岸水入侵臺灣海峽，形成的大陸沿岸水混合水與黑潮支流形成鋒面，其位置隨冷水勢力強弱而存在年間差異，冷水勢力以 2008 年最弱，2012 年最強，水文環境與仔至魚群聚亦隨之變動。環境因子及仔稚魚豐度之分布亦隨之變動。群聚分析結果顯示冬季台灣海峽各年度仔稚魚群聚大致可分為黑潮群(KC)及大陸沿岸水混合水群(MCCW)，群聚分布與鋒面位置大略吻合。*Diaphus* B 與 *Bregmaceros* spp. 為冬季黑潮最具代表性的物種；大陸沿岸水群之主要貢獻物種年間變化大，Scorpaenidae spp.最具代表性，Gobiidae spp.次之。此外，*Benthosema pterotum* and *Trichiurus* spp.則是在兩個水團都會共同出現的種類。黑潮群仔稚魚其分布受鋒面所侷限，其分布與鋒面位置相當吻合，而沿岸水群受鋒面限制則較不明顯，尤其當優勢種為底棲性魚類時最為明顯。BIO-ENV 分析顯示水溫與鹽度為影響冬季海峽仔稚魚群聚組成的主要因子。黑潮支流水團仔稚魚組成兼具了高多樣性與高均勻度；而大陸沿岸水團水文狀態較為複雜且變化較劇烈，因此只有少數適應性較強的物種可以生存，以致歧異度降低，均勻度亦較低。本研究對於台灣海峽冬季仔稚魚群聚之長期動態及與環境變動之關係提供了深入的探討。

關鍵詞：仔稚魚、鋒面、臺灣海峽、黑潮支流

前言

台灣四面環海，水文環境非常複雜，東側海域全年均受高溫高鹽黑潮水影響，並於東北部海域形成地形性湧昇(Gong et al., 1995; Tang et al., 2000)。西側台灣海峽於冬季東北季風盛行期間主要受由北向南流之低溫低鹽大陸沿岸水及由南向北流之黑潮支流與部份南海表層水影響，形成大陸沿岸水混合水向北輸送(Chern and Wang, 1989; Gong et al., 1995; Lie and Cho, 2002; Gong et al., 2003; Hsieh et al., 2012; Chen and Wang, 2006)，並於海峽中部海域形成鋒面區(Jan, 2006)。黑潮水與陸棚水在台灣東北部交會形成黑潮鋒面，其位置與黑潮流向變化密切相關(Chang et al., 2008; Lee et al., 2013)，並且存在季節性變化。夏季時黑潮通常離陸棚南端較遠，並分為向東北流的主軸與向西流的分支，冬季時黑潮則離岸較近(Qu, 2003; Centurioni et al., 2004)。此外，黑潮於東海南部形成的湧升將

富含營養鹽的次表層水帶至表層，對東海的基礎生產力提供了相當的貢獻(Gong et al., 2003; Chen et al., 2004; Wu et al., 2008)。

環境特性的變動是影響魚類生活史早期存活率的主要影響因子(Houde, 2008)，並影響著未來魚類族群資源的加入量(Hsieh et al., 2007；Hsieh et al., 2011)。環境因子的變動，例如溫度、鹽度、餌料生物的多寡、競爭及海流輸送等，被認為是影響仔稚魚群聚的活存與分布的主要影響因子(Lough and Manning, 2001；Leis, 2006；Sassa et al., 2006；Sassa et al., 2008)。過去於台灣海峽曾有相關研究小範圍地探討有關季風系統對仔稚魚群聚的影響(Hsieh et al., 2011; Hsieh et al., 2012)，Hsieh et al., 2007 探討台灣周邊海域冬季仔稚魚的組成與分布，Chen et al., 2016 針對東海及台灣周邊海域冬季仔稚魚組成進行分析，Huang and Chiu, 1998、Hsieh and Chiu (2002)、Chen et al, 2014 及 Wang et al., 2018 等對臺灣北部東海南部黑潮入侵區域的仔稚魚與水文環境進行了相關研究，惟有關冬季海峽仔稚魚群聚年間變化之長期觀測資料則仍付諸闕如。

了解海洋環境因子對於仔稚魚豐度及群聚的影響，對於以生態系統為基礎的漁業管理是相當重要的資訊，而以單一或有限年間的資料進行推估具有相當高的不確定性。然而，由於冬季東北季風時期風勢強勁海象惡劣，海上採樣作業多難以進行，因此有關冬季時涵蓋整個臺灣海峽仔稚魚群聚相關研究相當不足，亦無法觀察年間變化。本研究對於台灣海峽冬季仔稚魚群聚之長期動態及與環境變動之關係提供了深入的探討，包含仔稚魚之組成、豐度、分布、優勢種與群聚結構以及其與水文環境及水團鋒面之關係，提供冬季期間仔稚魚初期生活史資訊，作為漁業資源評估的參考依據。

材料與方法

一、樣本採集與處理

本研究利用 2007-2013 年水試一號船於冬季(1 月)期間至臺灣海峽各測站蒐集的仔稚魚樣本及水文資料進行分析，測站位置如 Fig. 1 所示。採集仔稚魚所使用的網具為 ORI 浮游生物網，網口直徑為 160 cm，網目大小為 330 μm，網口中央結附流量計以計算網具過濾海水之體積。採集方式係將網具投放至水深 200 m (水深不足者施放至離底 5 m)，再以 1 m/s 速度斜拖上揚的方式進行採集，取得之浮游生物樣本以 5 - 10%的福馬林海水溶液保存。水文資料則利用溫鹽深儀 (Seabird 9-11 Plus) 投放至 200 m(水深不足則離底 5 米)取得各測站溫度與鹽度之連續資料，並利用輪盤採水器分層採集水樣，利用輪盤採水器於 5-150 m 進行分層採集，水樣以液態氮 (-196°C) 急速凍結。葉綠素甲 (Chl-a) 則分別使用 10 μm 篩絹及 0.7 μm 濾膜，逐級過濾浮游植物後遮光冷凍 (-20°C) 保存攜回實驗室，將濾後濾膜經 90%丙酮低溫萃取 14-24 小時後，以螢光光度計測定酸化前後的螢光值，計算出海域中葉綠素甲含量。各測站浮游動物樣本利用 Folsom 分割器以二分法將樣本分割為兩個子樣本，將子樣本中之全數仔稚魚置於解剖顯微鏡

(Nikon：SMZ645)下進行分類及計數。仔稚魚密度值 (N, abundance; inds./1000 m3)係以子樣本中個體數乘以二後除以浮游生物網濾水體積進行換算。

二、資料分析

本研究取用表層 5m 數值繪製水溫、鹽度、葉綠素甲水平分布圖，並取測站 42、44、47、50、54、56 觀察海峽溫言垂直分布情形。仔稚魚豐度值(abundance, ind./1000m^3) 係以個體數除以浮游生物網濾水體積進行換算，利用 Shannon-Wiener 物種歧異度指數(H´)(Shannon-Wiener's index of species diversity; Shannon and Weaver, 1963)及 Pielou´s 物種均勻度指數(J')(Pielou's index of evenness; Pielou, 1966)，藉以探討仔稚魚群聚組成特性。進行仔稚魚相似性的站間分群(cluster analysis)之前，先將仔稚魚豐度值標準化轉換成對數值 log(X+1)，減少因單一物種的個數差異過大所造成的分析誤差，並以 Bray-Curtis similarity 計算站間的相似程度(Bray and Curtis, 1957)，然後再以 Ward's linkage 的方法進行站間分群，並繪製各測站間之關係樹狀圖。利用無母數的相似性分析 ANOSIM (Analysis of Similarities) 分析以檢定各分類群間是否有顯著差異存在，再利用 SIMPER(Similarity Percentages – species contributions)分析找出各群中的主要特徵物種，並利用 PRIMER 軟體 (vers. 6.0) 中的 BIO-ENV procedure，找出能夠使生物變數相似度矩陣與環境因子矩陣的相關性(Spearman rank correlation, σw)最大，探討仔稚魚群聚組成與海洋環境因子間的關係(Clarke and Ainsworth. 1993; Clarke and Warwick, 2001)。

結果與討論

海域水文環境

台灣周邊海域水文環境受到冬季東北季風與夏季西南季風吹送作用，及海底地形的變化等因素影響，呈現明顯季節變化。冬季東北季風盛行期間，自台灣北部海域至台灣海峽南部均受到由北向南流之低溫低鹽大陸沿岸水影響。觀察表層水溫分布(Fig. 2a)，大陸沿岸水影響範圍之等溫線分布大致上與大陸沿岸呈平行，最低水溫出現於大陸沿岸區域，此南下的冷水團與向北輸送的黑潮支流暖水在海峽處形成鋒面，暖水團侷限於海峽南部，因此在台灣海峽可觀察到明顯的水溫梯度變化。冬季時台灣海峽水與入侵台灣東北部海域的黑潮水混合向東北方向流進入東海陸棚的中部(Lie and Cho, 2002)，本研究在台灣北部海域亦可發現明顯的溫度梯度變化。觀察表層鹽度分布(Fig. 2b)，亦可發現鹽度自大陸沿岸向海峽處增加，約略與海岸線平行。低鹽度的大陸沿岸水於臺灣海峽中部與高鹽的黑潮支流水交會，於北部海域則與黑潮水交會，在這兩個區域形成明顯的鋒面。

葉綠素甲濃度在大陸沿岸水水團內各測站約略呈現均勻分布(Fig. 2c)，濃度存在年間差異，與黑潮支流水團相較，差異不大。葉綠素甲在西南海域黑潮支流水團則較容易出現高值區。在浮游動物豐度的部分(Fig. 2d)，黑潮支流水團的豐

度較高且在各年間呈現穩定趨勢，大陸沿岸水團之豐度則普遍較低(2008、2009年除外)，本研究雖未探討浮游動物種類組成，推測黑潮水與大陸沿岸水之種類組成應有明顯差異，鋒面位置形成不同水團之浮游動物豐度分布界線。仔稚魚豐度在大陸沿岸水水團內明顯較低(Fig. 2e)，且有許多測站是出現完全未捕獲仔稚魚的狀態，年間差異不大；黑潮支流水團較高，豐度存在年間差異小。比較 2008、2009 年大陸沿岸水團之浮游動物豐度與葉綠素甲濃度分布(Fig. 2c, 2d)，可發現此兩年之葉綠素濃度均低，然浮游動物豐度均偏高，顯示兩者間並非呈正相關之趨勢，葉綠素甲應非動浮豐度之限制因子，推論冬季時應有其他因子導致大陸沿岸水團之動浮豐度變化。比較 2008、2009 年大陸沿岸水團之仔稚魚豐度與浮游動物豐度分布(Fig. 2d, 2e)，可發現此兩年之浮游動物豐度均偏高，然仔稚魚豐度並未隨之較高，顯示兩者間並非呈正相關之趨勢，推論冬季時餌料(浮游動物)並非仔稚魚豐度之限制因子。

本研究透過繪製溫鹽剖面圖(Fig. 3)，冬季期間海峽水團因季風強烈吹襲垂直混合均勻無成層現象。2007 年低溫低鹽的大陸沿岸水混合水入侵海峽至海峽中部與溫暖高鹽的黑潮支流水交會，在測站 42 與 44 間可觀察到強烈的溫度梯度存在，混合水之北界則位於海峽北部測站 50 與 54 間，與北台灣黑潮支流水交會。2008 及 2009 年，冷水勢力弱退縮至海峽北部，鋒面位置向北移至測站 44 與 47 之間，北界則位於測站 54 與 56 之間。2010 年之情況亦類似。在 2011 年，寒冷的大陸沿岸水在測站 47 附近的位置出現。2012 年大陸沿岸水勢力最為強烈，其向南抵達海峽南部測站 44、42、37、38 的位置。2013 年，水團鋒面亦相當明顯，冷水團範圍界於測站 44-54 間，大陸沿岸水盤據於測站 44 的位置。此外，參考前人相關研究劃分水團(Gong et al., 1996; Ichikawa and Chaen, 2000; Jan et al., 2006)，可得到各測站所屬水團，主要可分為黑潮水、大陸沿岸水、及混合水，CCC 水溫<16.5℃，鹽度介於 30.7–33.7 psu ，MCCW 水溫介於 16.5–19.8 ℃，鹽度則介於 33.0–33.9 psu；餘高溫高鹽者為黑潮水團。依據水團交界繪製各航次鋒面位置，結果如 Fig. 4 所示，鋒面位置在不同年度間均有些微差異。大陸沿岸水在各年間入侵臺灣海峽的狀態均有差異，各年間的鋒面位置亦隨之變動，2008 年大陸沿岸水勢力較弱(Fig. 4b)，鋒面位置退縮至海峽中北部，2012 年大陸沿岸水勢力最強(Fig. 4f)，鋒面位置來到海峽南部，海峽內之溫鹽特性、浮游動物、仔稚魚豐度分布等均隨之變動。

仔稚魚分群及優勢種

各航次仔稚魚種類組成經由聚類分析所得樹狀圖如 Fig. 4 所示，各分群依據地理位置予以命名。2007 年仔稚魚群聚可分為 4 群(Fig. 4a)，位於黑潮支流及北部海域黑潮流域的測站乃命名為黑潮 I 群(Kuroshio subgroup I; K1)及黑潮 II 群(Kuroshio subgroup II; K2)，位於大陸沿岸水團內的測站則命名為大陸沿岸水混合水 I 群(Mixed China Coastal Water subgroup I; M1)及混合水 II 群(Mixed China Coastal Water subgroup II; M2)。2008 年仔稚魚群聚同樣可分為 K1、K2、M1 等

三群(Fig. 4b)。2009 年分為 K1、M1 兩群(Fig. 4c)。2010 年分為 K1、K2、M1 等三群(Fig. 4d)。2011 年分為 K1、M1 兩群(Fig. 4e)。2012 年分為 K1、M 1 兩群(Fig. 4f)。2013 年分為 K1、M 1、C2 等三群(Fig. 4g)。本研究於 2007-2013 年間共採得 5774 尾仔稚魚，分屬於 80 科 143 個類別，各航次內分群前五優勢種如 Table 1 所示，此外並計算個優勢物種在所有航次間出現的頻率百分比。黑潮群(K1、K2)中常見的優勢種多是由中層魚類所組成，年間變化較小，包括了七星底燈魚 *Benthosema pterotum*、眶燈魚屬 *Diaphus* B 等，在各年度都是主要的組成種類，在個航次間的出現率為 100%，海鰗鰍 *Bregmaceros* spp.則達 71.4%。大陸沿岸水群(C1、C2)中較常見的優勢種為底棲性種類，優勢種類多，鮋科 Scorpaenidae spp.、蝦虎科 Gobiidae spp.，出現頻率達 57.1%。此外，海鰗鰍 *Bregmaceros* spp. 及帶魚 *Trichiurus* spp.在各水團都會出現，亦為常見優勢種。相較之下，黑潮群的優勢種類組成較穩定，年間變化較小，大陸沿岸水群優勢種種類較多，年間組成變化大。

多樣性指數

在物種歧異度(H′)的部分(Fig. 5)，黑潮支流水團(K1)物種歧異度較高(K2 為黑潮北部海域水團但因測站數少故歧異度低)，而大陸沿岸水團(M1)之歧異度值則相對較低。在物種均勻度(J′)方面(Fig. 4)，黑潮支流水團(K1)及黑潮北部海域水團(K2)的均勻度較高，而大陸沿岸水團之均勻度則普遍較低，顯示仔稚魚群聚較易出現明顯優勢種。2012 年 K1 均勻度低是因為 Mugilidae spp.在測站 34 大量出現(713.9 ind./1000m^3)。2011 年 M1 的多樣性及均勻度低是因為 *Engraulis japonicus* 大量出現，佔該年度仔稚魚組成 67.93%，2013 年則是因為蝦虎大量出現，佔該年度仔稚魚組成 69.12%。黑潮是屬相對水溫等性質較為穩定的大洋性水團，因此適應於此環境的仔稚魚種類會較為豐富，仔稚魚組成兼具了高多樣性與高均勻度；而大陸沿岸水團水溫低且受到黑潮支流及南海表層水交互作用的影響，水文狀態較為複雜且變化較劇烈，因此只有少數適應性較強的物種可以生存，且由於不同水團間的鋒面區富含營養鹽，造成某物種大量出現，以致歧異度降低，均勻度亦較低。

水團、鋒面與仔稚魚群聚

本研究利用各測站溫鹽數據繪製溫鹽剖面圖(T-S diagram)，參考前人相關研究(Gong *et al.*, 1995; Ichikawa and Chaen 2000; Jan *et al.*, 2006)，定義各測站所屬水團(黑潮水、大陸沿岸水、混合水)，所得結果標識於 Fig. 4，水團交界鋒面位置如 Fig. 4 所示。2007 年冬季大陸沿岸水向南入侵至海峽 st40、st41、st43 位置(Fig. 4a)，在北部則與黑潮水 st51、st53、st54 交界，鋒面形成仔稚魚群聚的明顯分界，大陸沿岸水內測站之豐度明顯較低，許多測站無捕獲記錄。2008 年沿岸水入侵位置偏北(Fig. 4b)，南界至海峽北部 st46、st47、st49，北界則位於 st53、st54，屬大陸沿岸水之仔稚魚群聚分布於海峽南、北鋒面兩側且鋒面外屬黑潮水

測站者之豐度較高(Scorpaenidae spp.及 *Trichiurus* spp.為主要貢獻物種)。2009 年沿岸水入侵海峽南界位置與 2008 年接近(Fig. 4c)，北界位置相同，沿岸水仔稚魚群聚則越過南界鋒面。2010 年沿岸水入侵海峽南界位與 2009 年接近(Fig. 4d)，北界位置略有差異(至 st56)，沿岸水內測站之豐度明顯較低，許多測站無捕獲記錄，屬大陸沿岸水之仔稚魚群聚亦分布於南部鋒面兩側，黑潮群 K2 亦分布於北部鋒面之內側(Bregmaceros spp.及 Gobiidae spp. 為主要貢獻物種)，水團鋒面與仔稚魚群聚交界較不明顯。2011 年鋒面南界位置與 2007 年類似(Fig. 4e)，較為偏南，鋒面與群聚分界大致吻合。2012 年沿岸水入侵位置為各年度中最南邊 st37、st38(Fig. 4f)，北界亦偏南 st50、st52；2013 年沿岸水入侵位置同樣偏南(Fig. 4g)，北界則達 st53、st54，影響範圍為各年度中最大，黑潮水團仔稚魚群聚分布越過南界鋒面。綜上可發現，大陸沿岸水勢力存在年間變化，入侵海峽之位置各有消長，鋒面兩側不同水團之仔稚魚豐度有明顯差異，仔稚魚群聚與沿岸水及黑潮水水團鋒面位置在部分年度吻合(2007、2011、2013)，2008、2010、2012、2013 年兩者位置則略有差異。

SIMPER 分析

2007-2013 年航次各群內相似度(物種貢獻度)及群間差異度百分比如 Table 2 所示。2007-2013 年各航次仔稚魚分群之群間組成差異度均相當高(2013 年 K1、M2 差異度最低，亦達 88%以上)。黑潮群(K1、K2)之群內相似度均較低(2010 年稍高)，大陸沿岸水群(M1、M2)之群內相似度均較高，主要係因黑潮群之種類組成較複雜，沿岸水群則較單純。觀察 2007-2013 年各航次中黑潮群之主要貢獻物種，*Diaphus* B 與 *Bregmaceros* spp.為各年度中出現頻率最高的類別，*Diaphus* B 僅 2011、2012 年非屬主要貢獻物種，*Bregmaceros* spp.僅 2013 年非屬主要貢獻物種，此二類別在黑潮各測站的分布最均勻，為冬季黑潮最具代表性的物種；大陸沿岸水群之主要貢獻物種年間變化大，最具代表性的為 *Engraulis japonicus* (2011、2013)、Scorpaenidae spp. (2008、2010)及 *Trichiurus* spp. (2008、2012)為主要貢獻物種，分別僅在 2 個年度為主要貢獻物種，且冬季大陸沿岸水仔稚魚群聚常見單一類別為主要貢獻物種的情形。2007 年各分群之群間差異度均達 95%以上。K1 群內相似度不高(15.41%)，其中貢獻群內相似度最高的種類為 *Trichiurus* spp.與 *Diaphus* B。雖然 Labridae spp.為 K1 群中豐度最高的類別(佔群內總豐度 8.48%)，但由於集中出現於測站 36(49.02 ind./1000m^3) 與測站 37(48.66 ind./1000m^3)，因此並對於群內測站間相似度並無太大貢獻。K2 群內相似度亦不高(16.7%)，僅有 2 測站，群內相似度完全由裸蜥魚屬 *Lestidium* spp.此一類別所貢獻。C1 群位於海峽西側之 st43、44，群內相似度達 97.75%，相似度完全由 Triglidae spp.所貢獻。C1 群位於海峽之 st41、46，相似度完全由 Callionymidae spp.所貢獻。2008-2013 年各分群結果詳如 Table 2，整體而言，眶燈魚 *Diaphus* B 及海鰗鰍 *Bregmaceros* spp.為最常出現的貢獻種，在 7 個航次中均分別出現 5 次；M 群中，日本鯷分別於 2011 及 2013 年為優勢類別，鮋科 Scorpaenidae spp.在 2008

及 2010 年為優是類別，帶魚屬則是在 2008 及 2012 為優勢類別。

仔稚魚群聚與水文環境之關係

BIO-ENV 分析是找出能夠使生物變數相似度矩陣與環境因子矩陣的相關性(Spearman rank correlation, σw)最大，在 MDS 圖上看得出，兩者的分布形式最為接近，也就是這些因子最能解釋為何這些仔稚魚測站會被分在同一組。透過 BIO-ENV 分析顯示，仔稚魚群聚分布形式與環境因子分布形式，兩者有著中度的相關性，而這些因子的組成中，以溫度、鹽度為主要的因子。也就是說，臺灣海峽冬季仔稚魚群聚分布形式，主要受海域的溫鹽影響。

結論與建議

1. 冬季東北季風盛行期間，大陸沿岸水入侵臺灣海峽與黑潮支流形成鋒面，位置存在年間差異，環境因子及仔稚魚豐度之分布亦隨之變動。
2. 臺灣海峽仔稚魚群聚大致可分為黑潮群及大陸沿岸水群，群聚分布與鋒面位置大略吻合，鋒面兩側仔魚豐度有明顯差異；鋒面對黑潮群仔稚魚形成明顯分佈界線，而沿岸水群中的底棲性魚類分布則較不受鋒面影響。
3. 在分布上，眶燈魚與海鰗鰍為冬季黑潮最具代表性的物種， 在站間分布最均勻；沿岸水群之主要貢獻物種年間變化大，日本鯷、鮋科、帶魚較具代表性。
4. 在數量上，冬季黑潮群優勢種多是由中層魚類所組成，組成較穩定，七星底燈魚、眶燈魚、海鰗鰍、帶魚為最常見的類別；沿岸水群常見的優勢種多是由底棲魚類所組成，年間組成變化大，蝦虎、鮋科、七星底燈魚較具代表性。
5. 臺灣海峽冬季仔稚魚群聚分布，主要受水溫及鹽度分布形式影響，兩者有著中度的相關性。

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1072810

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Abstract

This study demonstrated the interannual variations of larval fish assemblages associated with ocean fronts in the Taiwan Strait (TS), based on seven consecutive cruises in winter from 2007 to 2013. The cold and low-saline China Coastal Current

(CCC) and Mixed China Coastal Water (MCCW) intruded into the TS with annual variations, which were weakest in 2008 and strongest in 2012, and impinged with the warm Kuroshio Branch Current (KBC). Consequently, the fluctuation in the strength of cold water masses resulted in the variability of the location of the frontal zones, as well as the distributions of environmental variables and larval fish assemblages. The cluster analysis showed that the ichthyoplankton community in the TS was mainly structured in two assemblages characterized by differing environmental conditions. The composition of the warm KC assemblage was relatively stable, characterized by *Bregmaceros* spp. and *Diaphus* B. On the other hand, the cold MCCW assemblage showed drastical variations among years, and Scorpaenidae spp. was thought to be most representative, followed by Gobiidae spp.. Besides, *Benthosema pterotum* and *Trichiurus* spp. were common in both KC and MCCW regions. The distribution of KC assemblages showed sharp boundaries in the frontal zones, while the changes in assemblage structure between frontal zones were gradual for MCCW assemblages, particularly when demersal taxa dominated. BIO-ENV procedure indicated that the surface temperature and salinity were the environmental variables most strongly associated with differences in assemblage structure in the TS during winter. This study provides crucial information about the status of the larval fish community and presents a better understanding of the long-term dynamics and the influence of environmental fluctuations in the TS during winter.

Keywords: fish larvae, fronts, Taiwan Strait, Kuroshio Branch Current

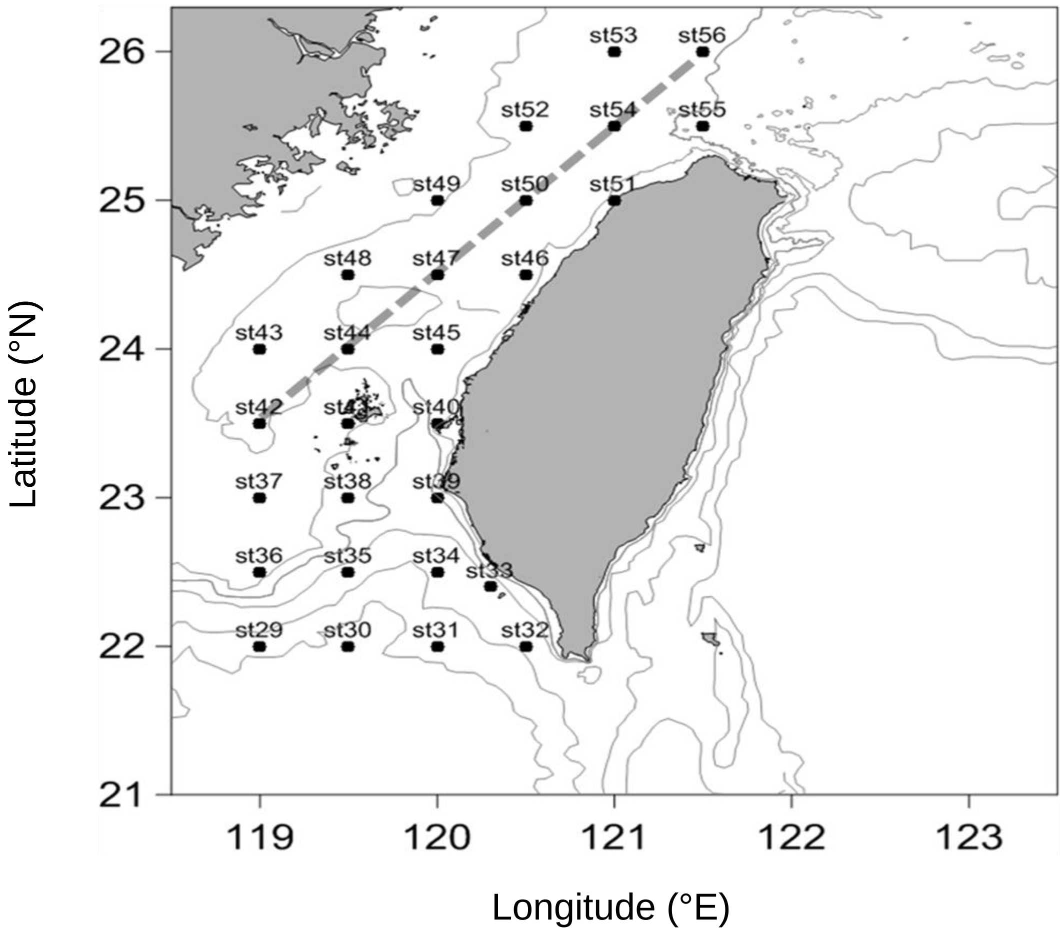


Fig. 1 Sampling stations for fish larvae and environmental factors in the Taiwan Strait in winter during 2007–2013. Grey dotted line illustrates the transect for the vertical profiles of temperature and salinity

1072810

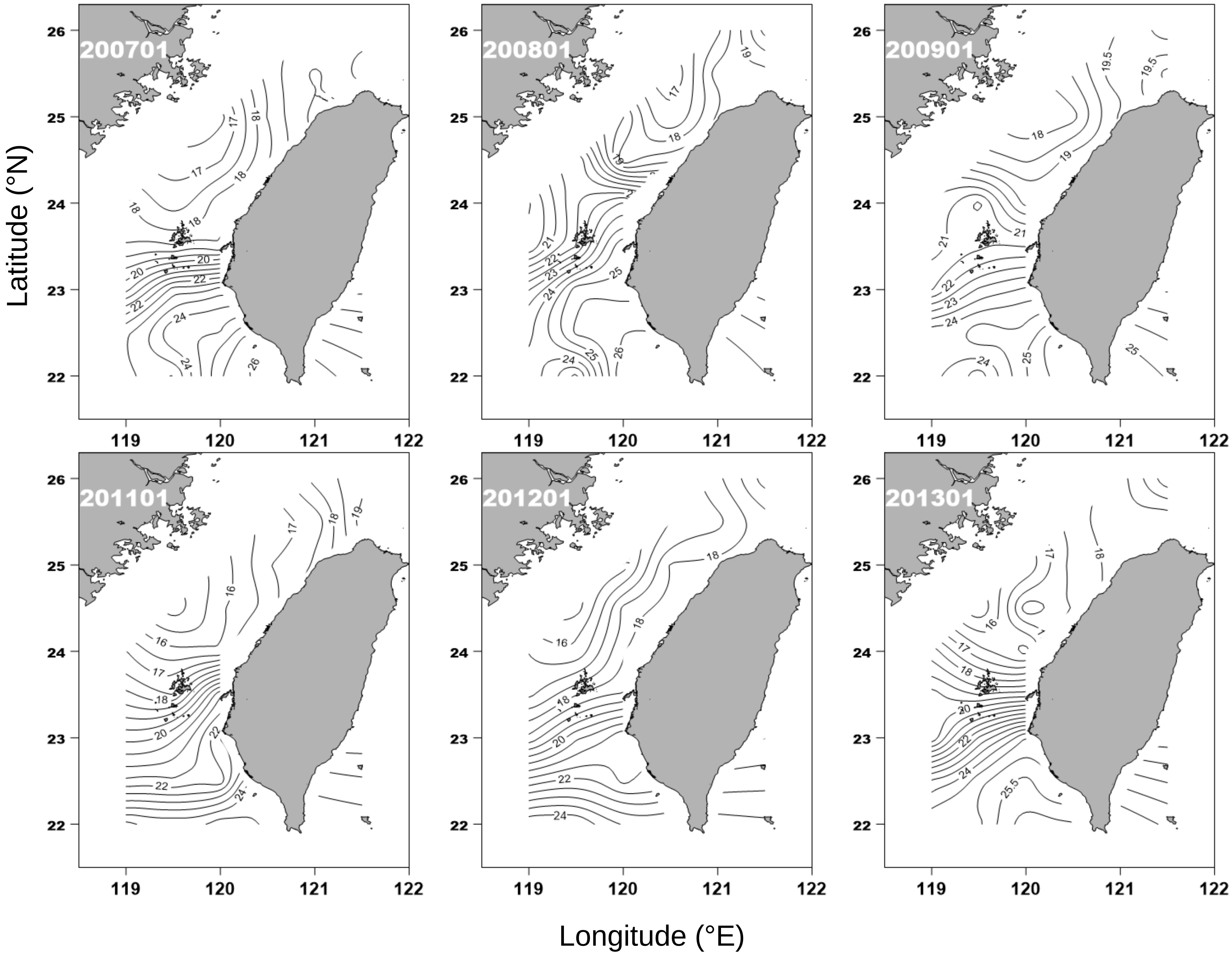


Fig. 2a The distribution of sea surface temperature (℃) in the Taiwan Strait in winter during 2007– 2013

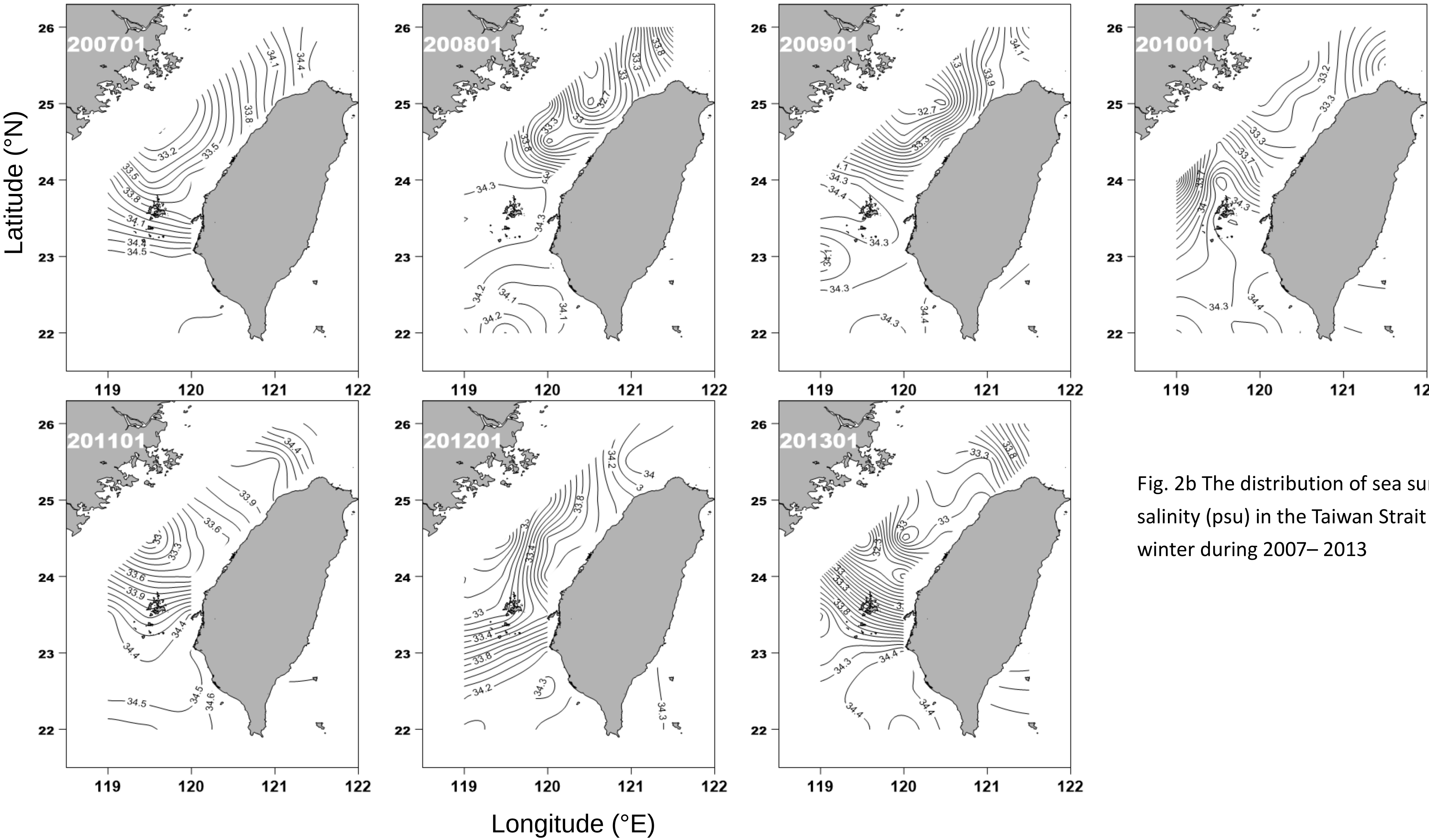


Fig. 2b The distribution of sea surface salinity (psu) in the Taiwan Strait in winter during 2007– 2013

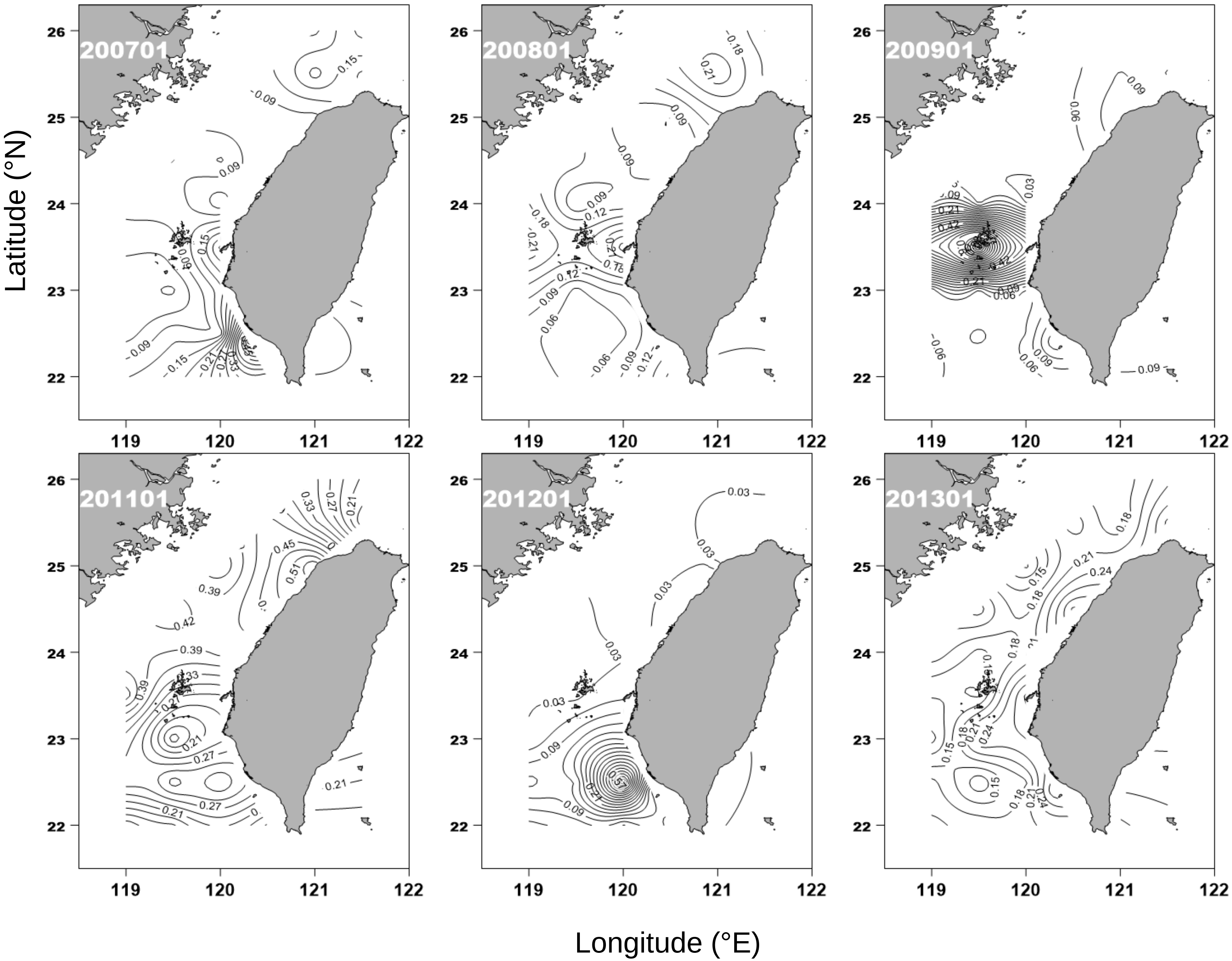


Fig. 2c The distribution of chlorophyll-a (mg/m^3) in the Taiwan Strait in winter during 2007–2013

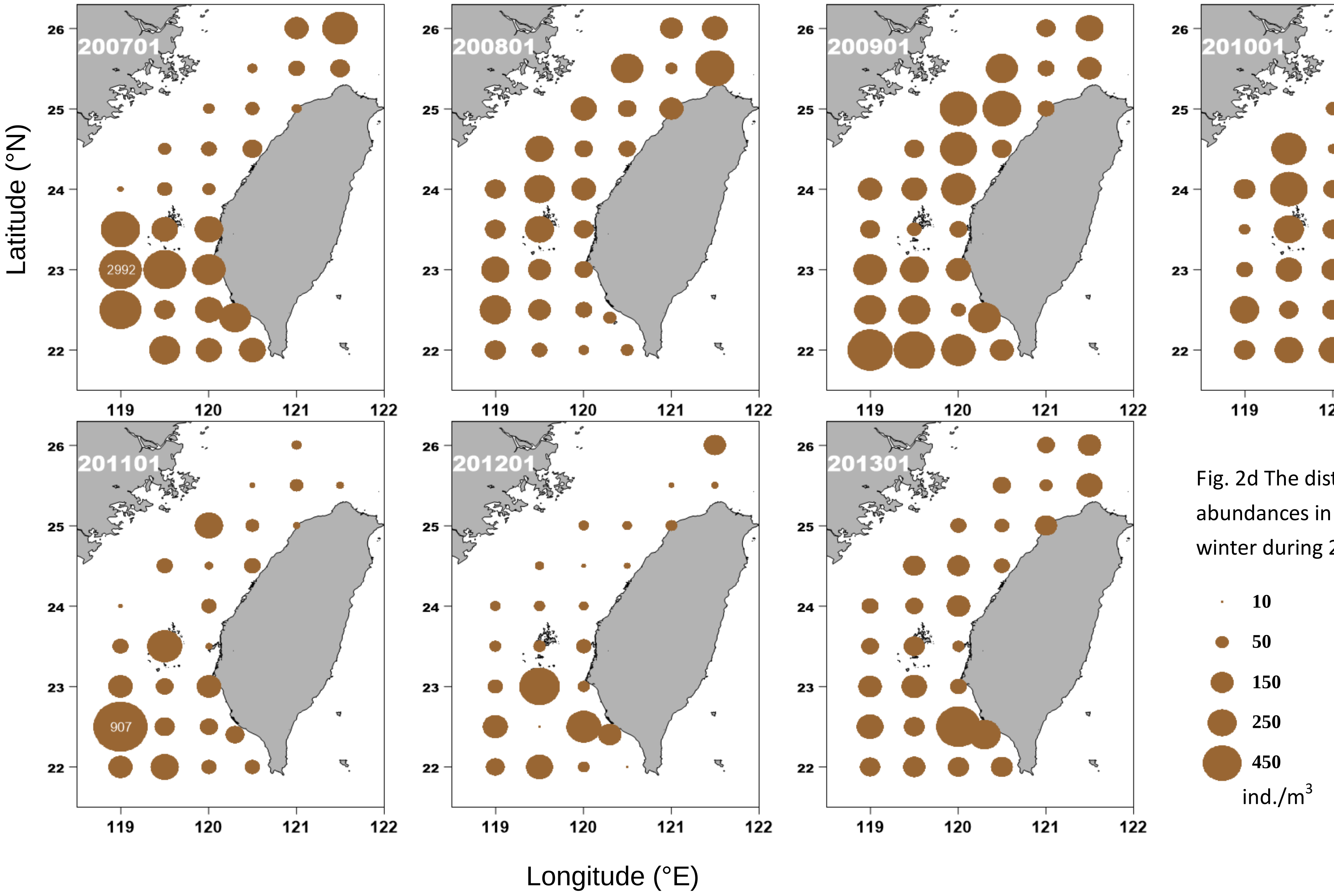


Fig. 2d The distribution of zooplankton abundances in the Taiwan Strait in winter during 2007-2013

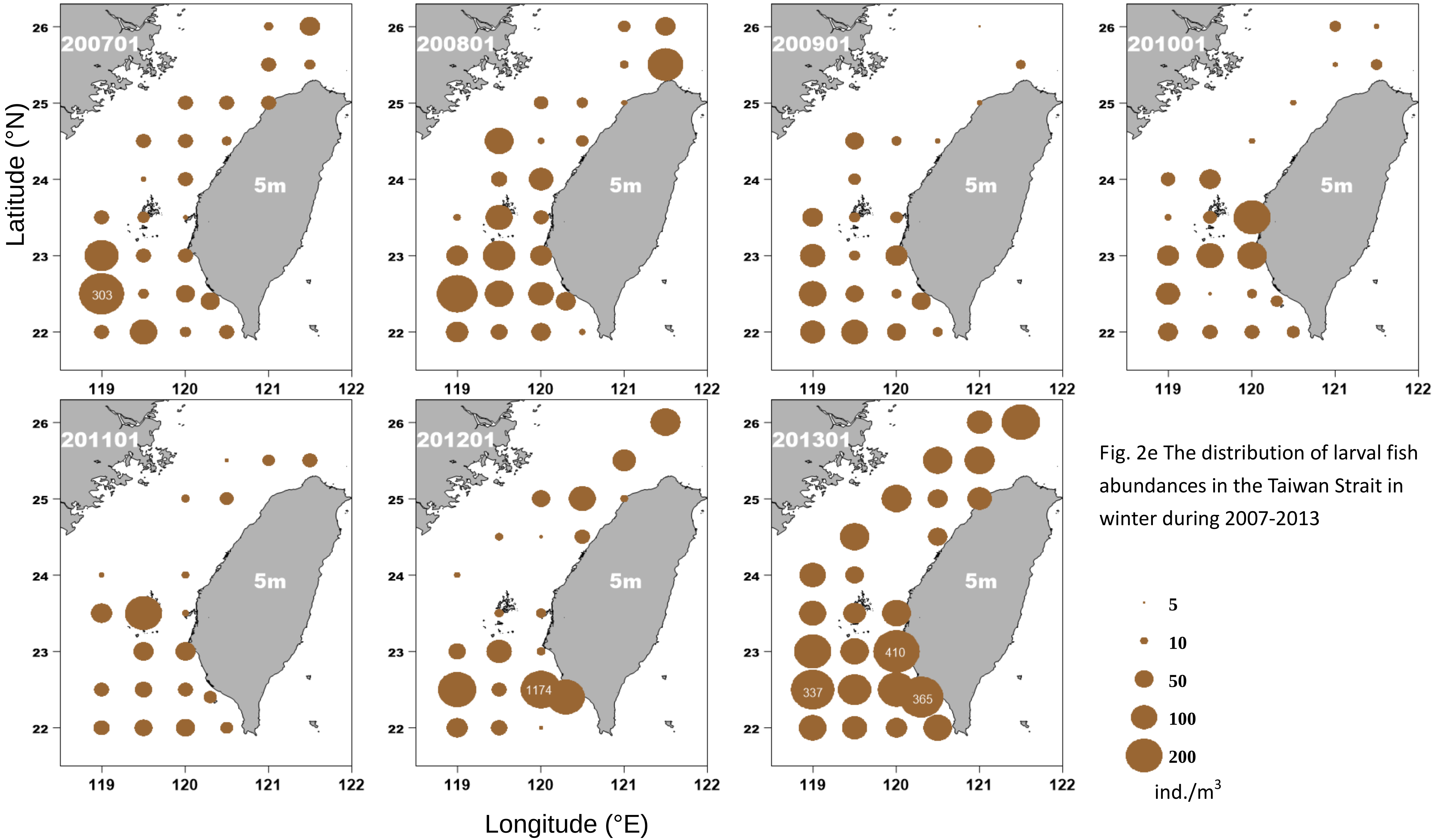


Fig. 2e The distribution of larval fish abundances in the Taiwan Strait in winter during 2007-2013

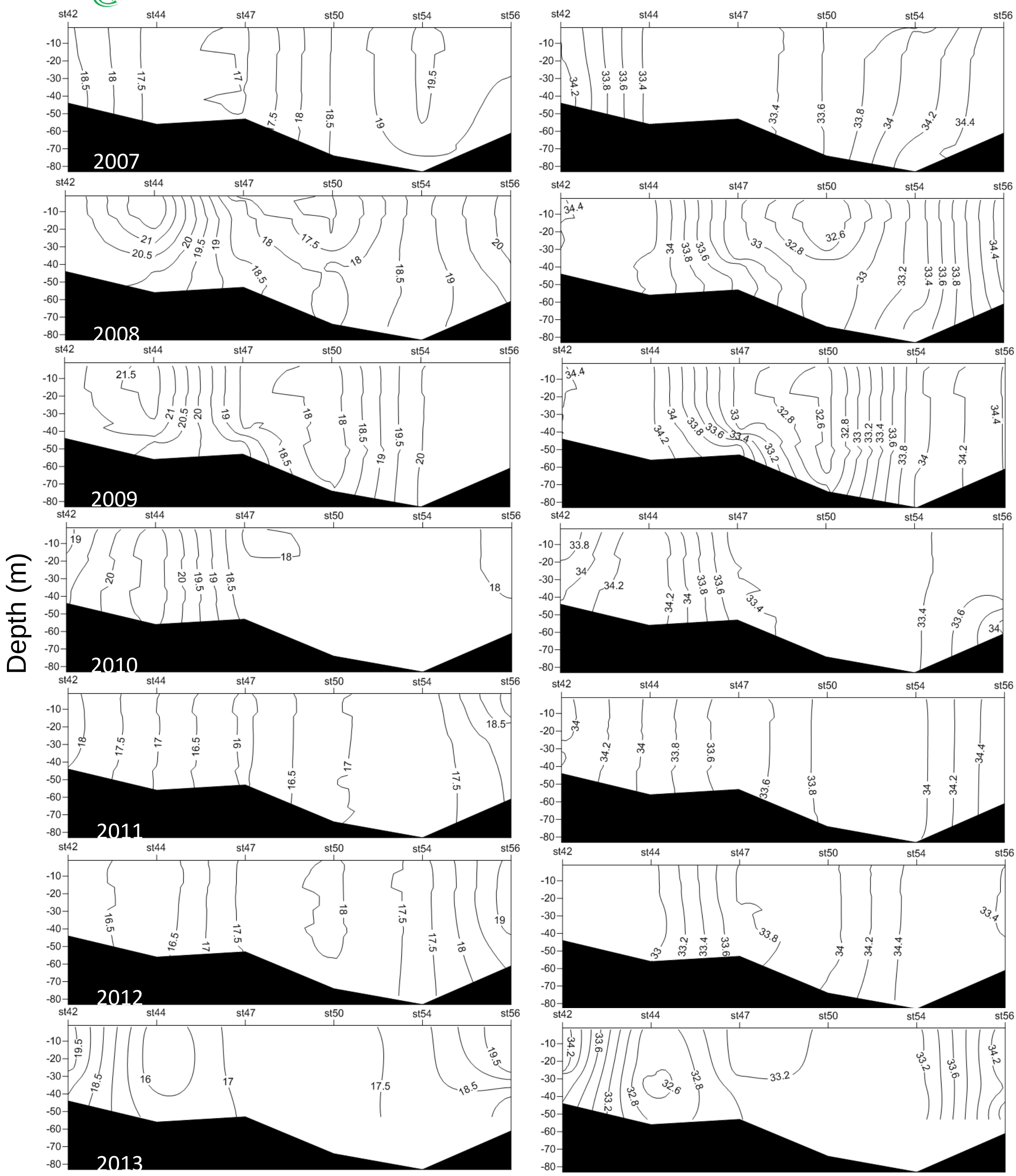


Fig. 3 Vertical profiles of temperature (°C; left panel) and salinity (psu; right panel) of the transect in the Taiwan Strait in winter during 2007-2013

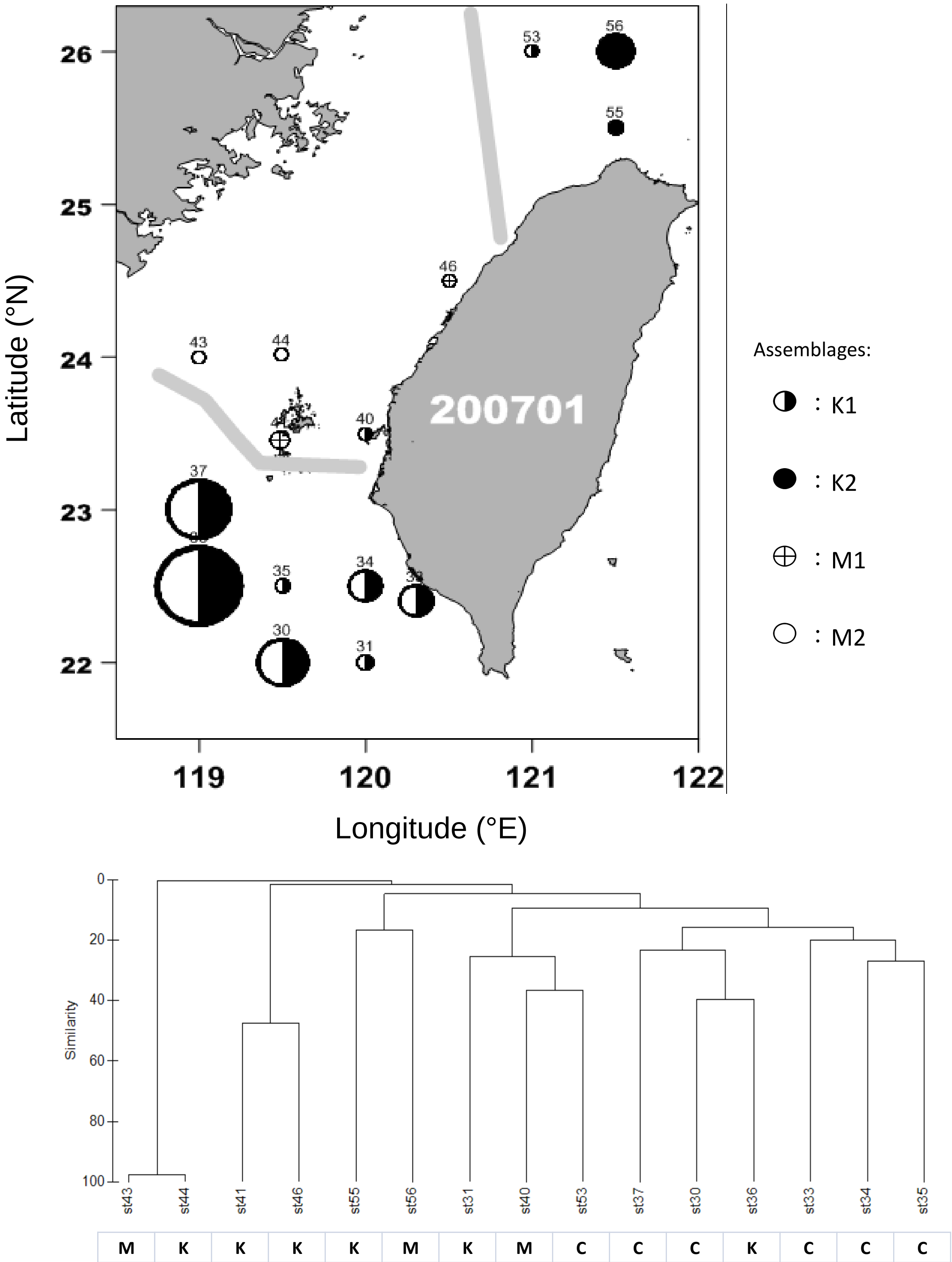
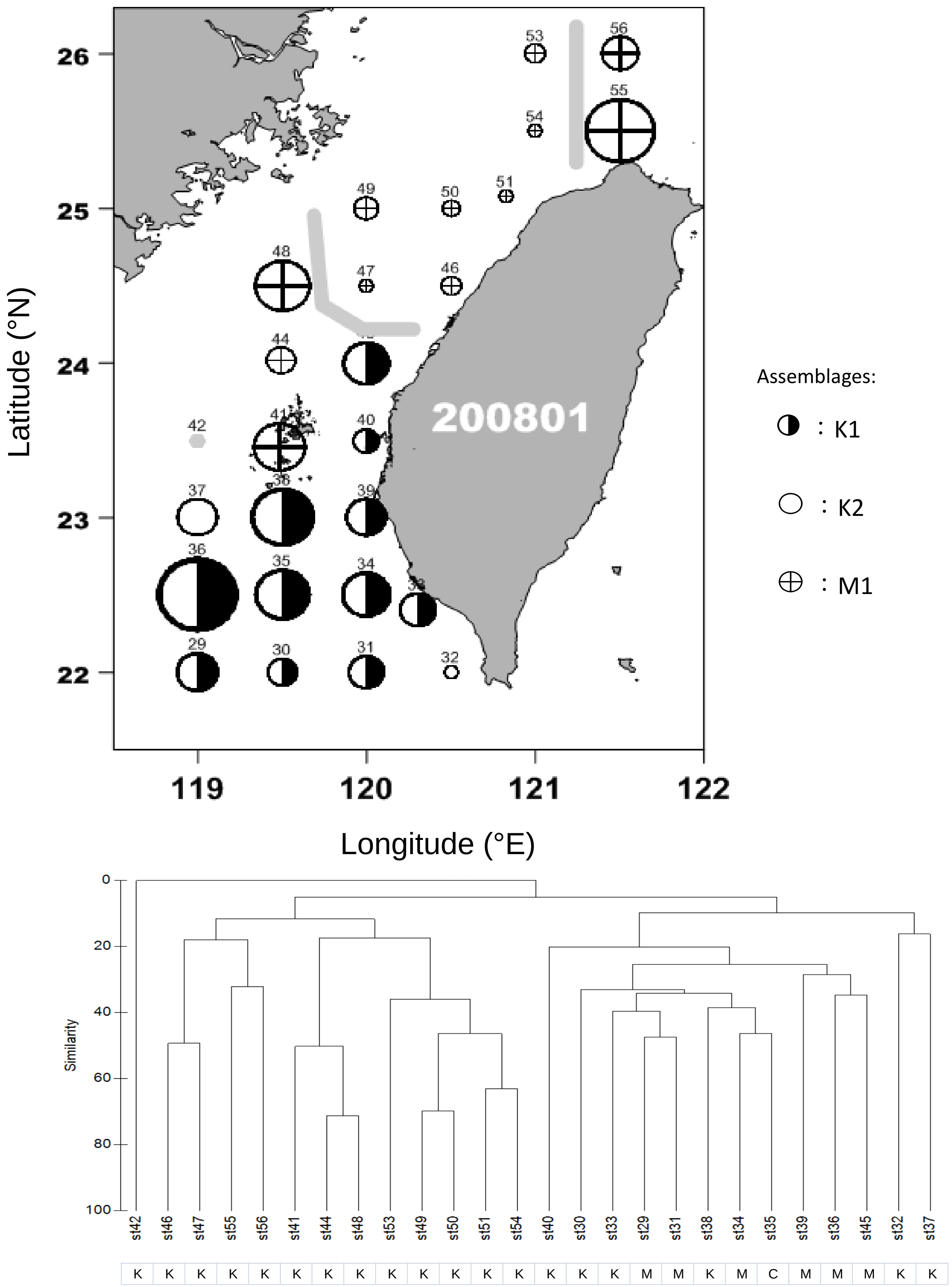


Fig. 4a The spatial distribution of larval abundance for corresponding groups determined from cluster analysis in the TS in winter 2007 and the grey line indicates the boundary of water masses derived from the T–S diagram (upper). The dendrogram of cluster analysis based on Bray–Curtis similarity matrix of logarithmic abundance of larval fish (lower). K: Kuroshio Branch Current (KBC), C: China Coastal Current, M: Mixed China Coastal Water



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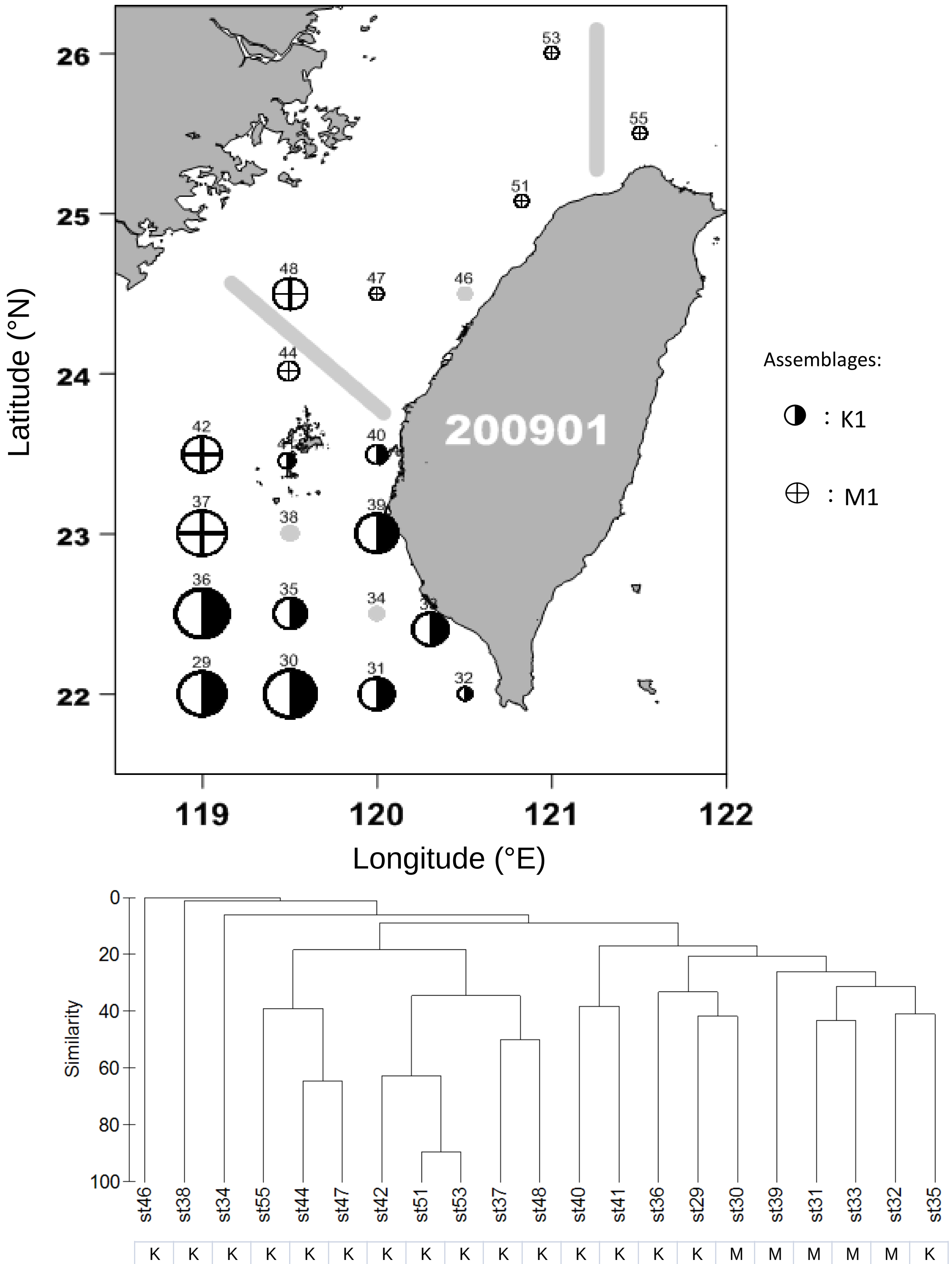

Fig. 4c The spatial distribution of larval abundance for corresponding groups determined from cluster analysis in the TS in winter 2009 and the grey line indicates the boundary of water masses derived from the T–S diagram (upper). The dendrogram of cluster analysis based on Bray–Curtis similarity matrix of logarithmic abundance of larval fish (lower). K: Kuroshio Branch Current (KBC), C: China Coastal Current, M: Mixed China Coastal Water

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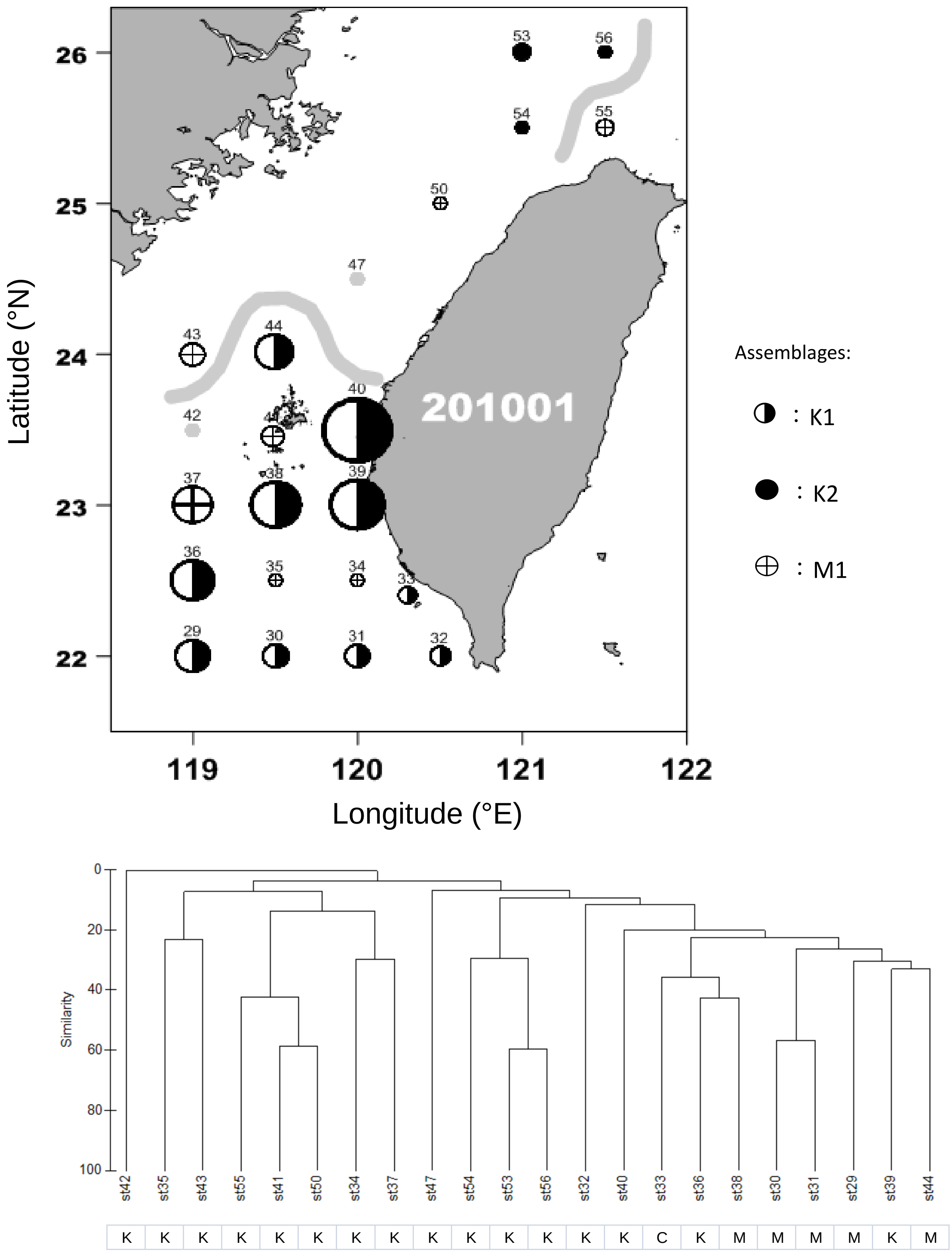

Fig. 4d The spatial distribution of larval abundance for corresponding groups determined from cluster analysis in the TS in winter 2010 and the grey line indicates the boundary of water masses derived from the T–S diagram (upper). The dendrogram of cluster analysis based on Bray–Curtis similarity matrix of logarithmic abundance of larval fish (lower). K: Kuroshio Branch Current (KBC), C: China Coastal Current, M: Mixed China Coastal Water

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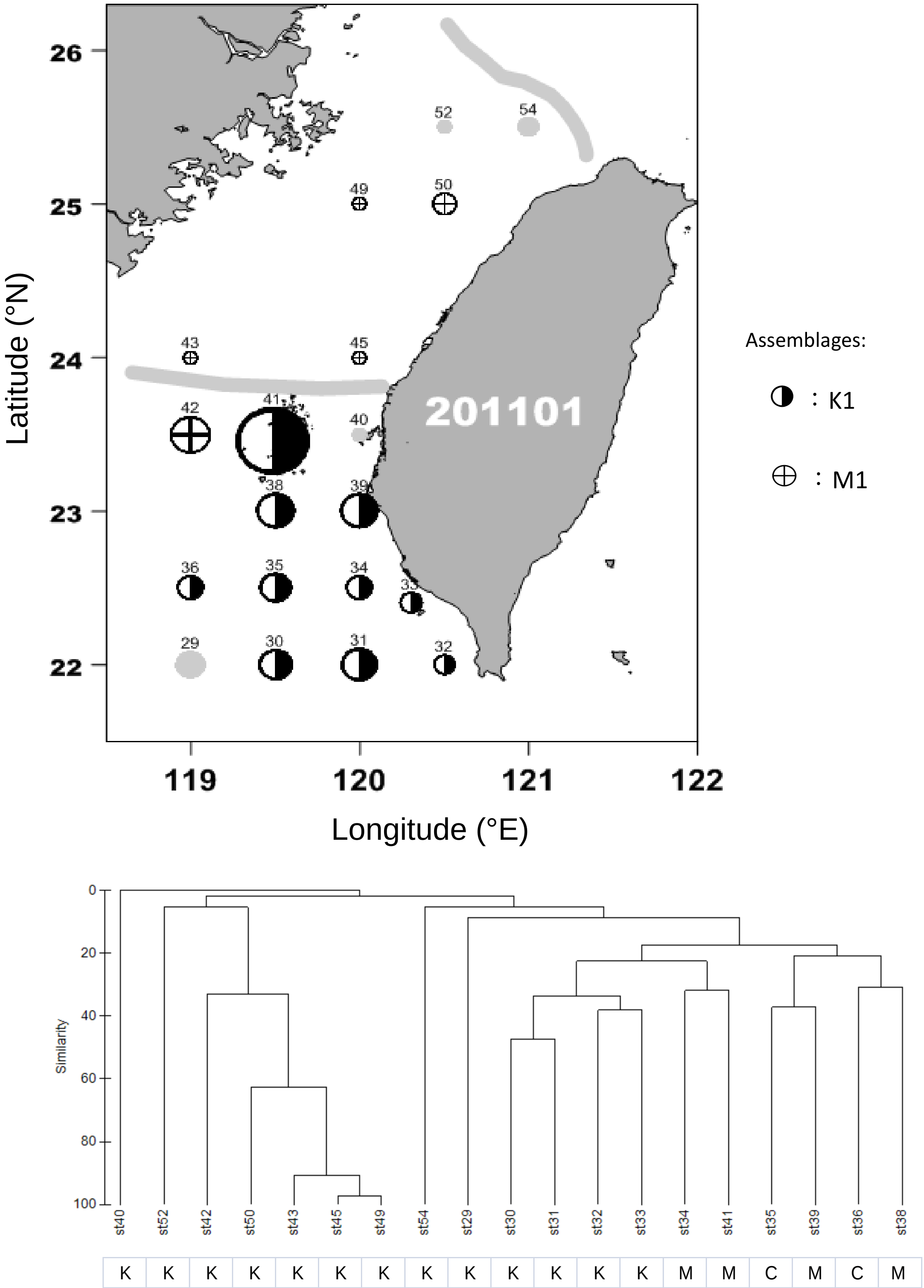

Fig. 4e The spatial distribution of larval abundance for corresponding groups determined from cluster analysis in the TS in winter 2011 and the grey line indicates the boundary of water masses derived from the T–S diagram (upper). The dendrogram of cluster analysis based on Bray–Curtis similarity matrix of logarithmic abundance of larval fish (lower). K: Kuroshio Branch Current (KBC), C: China Coastal Current, M: Mixed China Coastal Water

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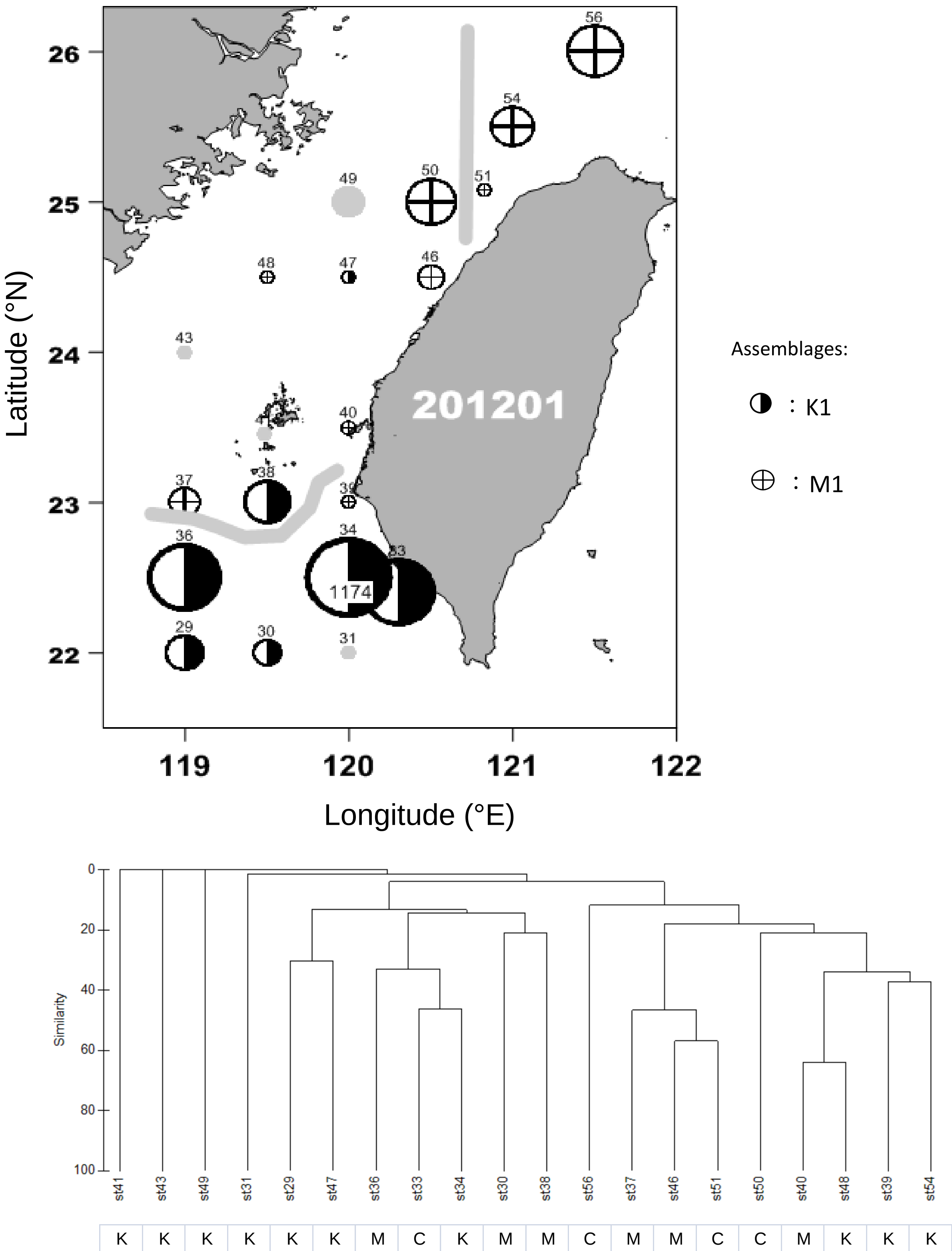

Fig. 4f The spatial distribution of larval abundance for corresponding groups determined from cluster analysis in the TS in winter 2012 and the grey line indicates the boundary of water masses derived from the T–S diagram (upper). The dendrogram of cluster analysis based on Bray–Curtis similarity matrix of logarithmic abundance of larval fish (lower). K: Kuroshio Branch Current (KBC), C: China Coastal Current, M: Mixed China Coastal Water

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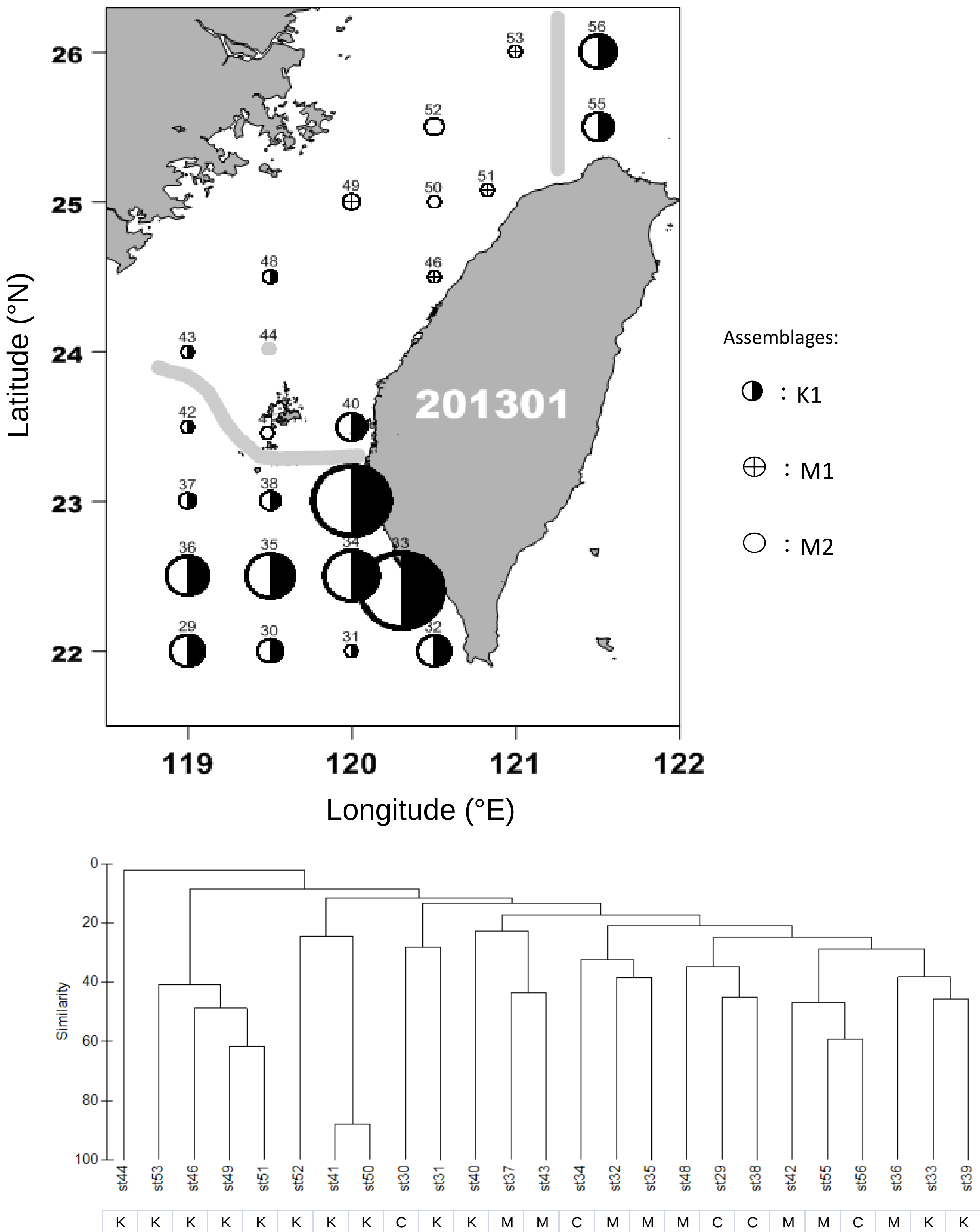

Fig. 4g The spatial distribution of larval abundance for corresponding groups determined from cluster analysis in the TS in winter 2013 and the grey line indicates the boundary of water masses derived from the T–S diagram (upper). The dendrogram of cluster analysis based on Bray–Curtis similarity matrix of logarithmic abundance of larval fish (lower). K: Kuroshio Branch Current (KBC), C: China Coastal Current, M: Mixed China Coastal Water

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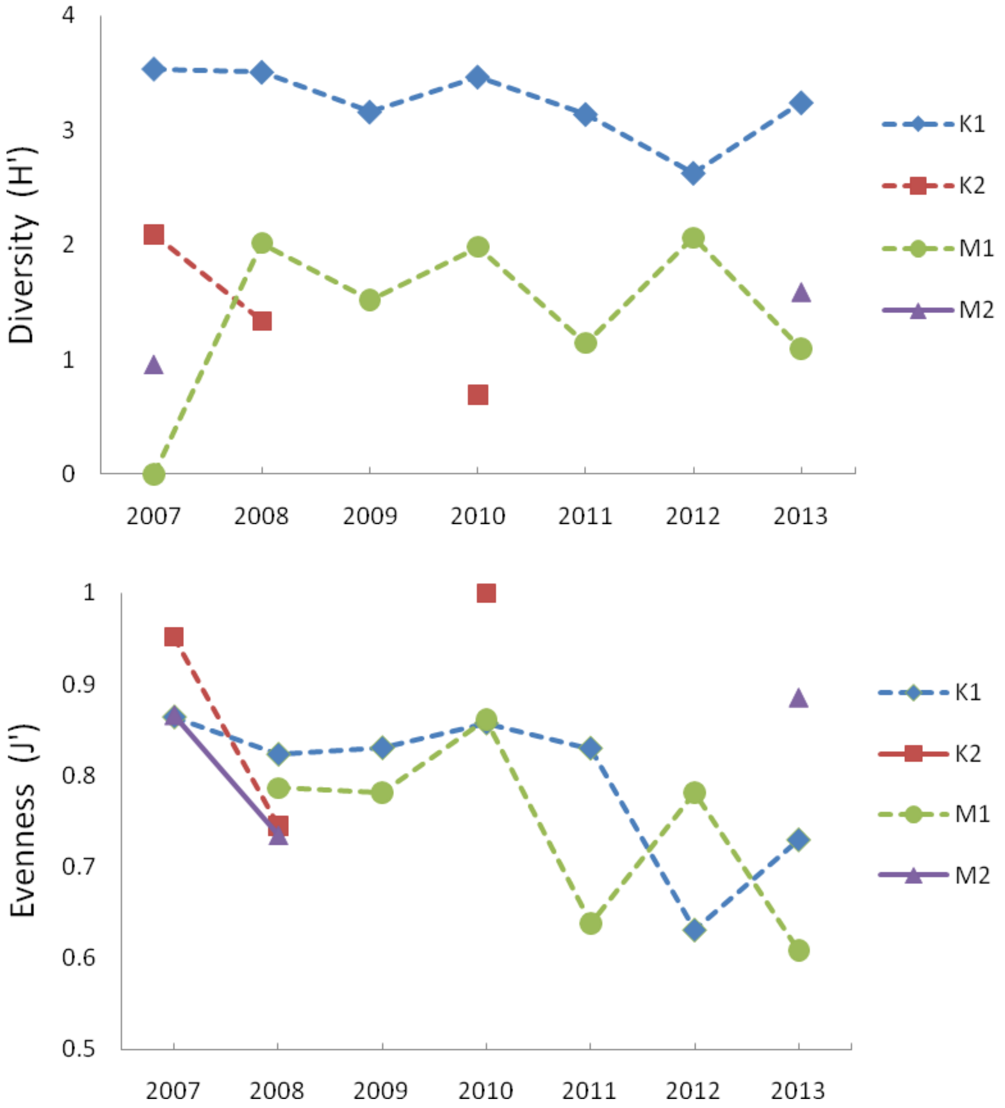

Fig. 5 Shannon’s diversity (H’) and Pielou´s evenness (J’) of each group derived from cluster analysis for each cruise during 2007–2013

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Table 1 The top five abundant taxa of each group based on the cluster analysis for each cruise in the Taiwan Strait in winter during 2007-2013

Group	2007	2008	2009	2010	2011	2012	2013
K1	Labridae spp. (8.48%)	*Diaphus* B (12.16%)	*Benthosema pterotum* (16.64%)	*Diaphus* B (13.64%)	*Bregmaceros* spp. (18.48%)	Mugilidae spp. (41.92%)	*Benthosema pterotum* (20.55%)
	Ammodytidae spp. (8.17%)	*Bregmaceros* spp. (11.97%)	*Diaphus* B (15.72%)	*Bregmaceros* spp. (10.74%)	*Sigmops gracilis* (13.24%)	*Benthosema pterotum* (11.06%)	*Diaphus* B (12.89%)
	***Trichiurus* spp. (7.43%)**	*Stomias nebulosus* (7.31%)	*Stomias nebulosus* (7.33%)	*Benthosema pterotum* (6.20%)	*Benthosema pterotum* (8.00%)	Callionymidae spp. (6.33%)	*Engraulis japonicus* (11.44%)
	Bothidae spp. (6.79%)	*Lampanyctus* spp. (5.45%)	*Bregmaceros* spp. (7.32%)	*Vinciguerria nimbaria* (5.62%)	*Diaphus* B (6.26%)	*Sigmops gracilis* (4.17%)	*Mugil cephalus* (7.12%)
	Diaphus B (6.11%)	*Benthosema pterotum* (3.89%)	*Myctophum obtusirostre* (4.39%)	*Trichiurus* spp. (5.40%)	*Trichiurus* spp. (5.13%)	*Diaphus* B (3.89%)	*Trichiurus* spp. (4.16%)
K2	*Scopelaurus* spp. (22.20%)	Bothidae spp. (44.58%)		*Bregmaceros* spp. (50.34%)			
	Lestidium spp. (16.68%)	*Lampanyctus* spp. (25.00%)		Gobiidae spp. (49.66%)			
	Stomias nebulosus (11.10%)	*Encrasicholina punctifer* (22.29%)					
	Benthosema pterotum (11.1%)	*Melamphaes leprus* (2.71%)					
	Lampanyctus spp. (11.10%)	Serranidae type 1 (2.71%)					
M1	Triglidae spp. (100%)	*Scomber australasicus (35.12%)*	*Benthosema pterotum* (47.61%)	Scorpaenidae spp. (29.32%)	*Engraulis japonicus* (67.93%)	*Trichiurus* spp. (32.30%)	Gobiidae spp. (69.12%)
		Benthosema pterotum (21.87%)	Scorpaenidae spp. (17.98%)	*Notoscopelus* spp. (14.65%)	*Sigmops gracilis* (6.57%)	Gobiidae spp. (23.03%)	*Benthosema pterotum* (10.22%)
		Bregmaceros spp. (13.37%)	*Encrasicholina heteroloba* (11.84%)	Callionymidae spp. (14.65%)	*Synodus* spp. (6.57%)	*Engraulis japonicus* (9.08%)	*Diaphus* A (8.15%)
		Trichiurus spp. (8.50%)	*Seriola* spp. (11.54%)	*Diaphus* B (13.01%)	*Benthosema pterotum* (6.57%)	Scorpaenidae spp. (7.31%)	Hoplichthyidae spp. (4.22%)
		Scorpaenidae spp. (5.77%)	Triglidae spp. (4.60%)	Apogonidae spp. (12.50%)	Gobiidae spp. (6.57%)	*Saurida* spp. (7.06%)	*Trichiurus* spp. (4.22%)
M2	Callionymidae spp. (59.84%)						*Saurida* spp. (37.57%)
	Pleuronectidae spp. (20.47%)						*Bregmaceros* spp. (23.70%)
	Gobiidae type 1 (19.69%)						*Engraulis japonicus* (16.19%)
							Ceratoscopelus warmingi (7.51%)
							Gobiidae spp. (7.51%)

Table 2 Similarity percentage (species contributions) within group and dissimilarity between groups detected by SIMPER routine for the fish larvae cluster groups in the Taiwan Strait in winter during 2007-2013

	SIMPER (Similarity Percentages–species contributions)			
2007	K1	K2	M1	M2
K1	Avg. similarity: 15.41% *Trichiurus* spp. (26.77%) *Diaphus* B (12.50%)			
K2	Avg. dissimilarity: 95.20%	Avg. similarity: 16.70% *Lestidium* spp. (100%)		
M1	Avg. dissimilarity: 99.39%	Avg. dissimilarity: 100%	Avg. similarity: 97.75% Triglidae spp. (100%)	
M2	Avg. dissimilarity: 97.98%	Avg. dissimilarity: 100%	Avg. dissimilarity: 100%	Avg. similarity: 47.473% Callionymidae spp. (100%)
2008	K1	K2	M1	
K1	Avg. similarity: 28.67% *Diaphus B* (27.77%) *Bregmaceros spp.* (12.84%)			
K2	Avg. dissimilarity: 90.29%	Avg. similarity: 16.15% *Lampanyctus spp.* (100%)		
M1	Avg. dissimilarity: 94.44%	Avg. dissimilarity: 98.35%	Avg. similarity: 21.46% Scorpaenidae spp. (36.52%) *Trichiurus* spp. (24.10%)	
2009	K1		M1	
K1	Avg. similarity: 23.05% *Diaphus B* (27.67%) *Bregmaceros spp.* (17.72%)			
M1	Avg. dissimilarity: 91.26%		Avg. similarity: 31.68% *Benthosema pterotum* (76.03%) *Encrasicholina heteroloba* (16.06%)	
2010	K1	K2	M1	
K1	Avg. similarity: 22.80% *Diaphus* B (26.17%) *Bregmaceros spp.* (23.31%)			
K2	Avg. dissimilarity: 90.67%	Avg. similarity: 39.60% *Bregmaceros spp.* (50.25%) Gobiidae spp. (49.75%)		
M1	Avg. dissimilarity: 94.68%	Avg. dissimilarity: 100%	Avg. similarity: 16.71% Scorpaenidae spp. (64.08%) *Notoscopelus spp.* (17.27%)	
2011	K1		M1	
K1	Avg. similarity: 17.32% *Bregmaceros spp.* (45.01%) *Sigmops gracilis* (12.54%)			
M1	Avg. dissimilarity: 98.23%		Avg. similarity: 41.68% *Engraulis japonicus* (95.69%)	
2012	K1		M1	
K1	Avg. similarity: 18.24% *Bregmaceros spp.* (47.40%) Bothidae spp. (6.01%)			
M1	Avg. dissimilarity: 96.11%		Avg. similarity: 23.12% Gobiidae spp. (60.84%) *Trichiurus* spp. (19.52%)	
2013	K1	K2	M1	
K1	Avg. similarity: 21.46% *Diaphus* B (30.01%) *Benthosema pterotum* (18.56%)			
M1	Avg. dissimilarity: 91.13%	Avg. similarity: 47.02% Gobiidae spp. (90.43%)		
M2	Avg. dissimilarity: 88.45%	Avg. dissimilarity: 92.02%	Avg. similarity: 45.83% *Bregmaceros spp.* (67.94%) *Engraulis japonicus* (32.06%)	

Table 3 Multivariate Spearman rank correlation between environmental variables and larval fish assemblages using BIO-ENV showing the best combinations of variables for each cruise in the Taiwan Strait in winter during 2007-2013

	Best variable combinations													
Variables	2007		2008		2009		2010		2011		2012		2013	
	σ_w	Selections	σ_w	Selections	σ_w	Selections	σ_w	Selections	σ_w	Selections	σ_w	Selections	σ_w	Selections
1 Depth	0.408	2,3	0.496	2,3	0.397	2—4	0.351	2,3	0.47	2,3	0.298	2,3	0.365	2,3
2 Temp. 5m	0.369	2—4	0.46	2,3,5	0.381	3,4	0.297	2—4	0.458	2	0.236	3	0.361	3
3 Salinity 5m	0.34	3,4	0.442	2—5	0.323	2,4	0.286	2,3,5	0.427	3	0.225	1—3	0.322	2
4 Chl-*a*	0.31	3,5	0.44	2,5	0.315	2,3	0.272	2	0.425	2—4	0.219	2,	0.278	1—3
5 Zoopl.	0.302	2—5	0.432	2—4	0.296	3	0.251	3,5	0.398	3,4	0.212	1,3	0.259	1,3
	0.295	3—5	0.422	2,4	0.267	2—5	0.244	2—5	0.376	2,4	0.176	2,3,5	0.249	2,3,5
	0.276	2,3,5	0.418	2,4,5	0.221	3—5	0.238	2,3	0.361	2,3,5	0.148	1—3,5	0.216	2—4
	0.243	4,5	0.36	1—3	0.213	2	0.223	2,4	0.352	2—5	0.14	1,2	0.216	1,2
	0.24	2,4	0.358	1—5	0.211	4	0.198	2,5	0.322	2,5	0.127	2—4	0.212	3,5