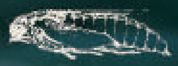
ECOLOGIA DE LES COMUNITATS DE MACROINVERTEBRATS EN RIUS MEDITERRANIS

A DIFERENTS ESCALES I NIVELLS D'ORGANITZACIÓ



ECOLOGY OF THE MACROINVERTEBRATE COMMUNITIES IN MEDITERRANEAN RIVERS

AT DIFFERENT SCALES AND ORGANIZATION LEVELS

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UNIVERSITAT DE BARCELONA

DEPARTAMENT D'ECOLOGIA

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Ecology of macroinvertebrate communities in mediterranean rivers at different scales and organization levels

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Narcís Prat
Maria Rieradevall
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Als rius

TEMPORALITAT

L’aspre migjorn
novament
ha cremat la tarda, i
gronxant els salzes de la ribera,
ha omplert l’aire
de borrissol,
i de foc.

El riu, altre cop eixut,
arrecera
larves de petits insectes
que damunt dels còdols eixorcs
esperen la pluja,
l’aigua
de la vida.

El capvespre ennegrit
amaga
una lluna solitària,
plora i esdevé tardorenc ruixat
per donar efímera vida
al sedegós
ecosistema.

L’època de pluges ha arribat,
la vida continua.

Agraïments

Ara que miro enrera, me n'adono que d'una manera o altra, la meva vida ha estat lligada als rius. Des de que era molt petitona (encara que tampoc és que hagi crescut gaire!), moltes persones m'han ajudat a descobrir el seu encant, despertant el meu interès pel seu coneixement i conservació. A tots ells, a totes les persones que estimen els rius i amb les que hem passat bons moments, voldria agrair-los-hi el seu recolzament en cada etapa de la meva vida personal i professional. Molts de vosaltres ja ho sabeu, si avui estic aquí, no ha estat per casualitat....

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...i a tots aquells macroinvertebrats aquàtics que de manera involuntària han donat el seu cos a la ciència...que no han estat pocs!.

Index

Resum

INTRODUCCIÓ

Els patrons i processos que tenen lloc en qualsevol ecosistema estan altament influenciats per l'escala espacial i temporal, i el nivell d'organització en que el sistema és analitzat, és a dir el com i el què és objecte d'estudi. L'efecte de l'escala en les comunitats d'organismes ha estat àmpliament debatut tant en els sistemes terrestres com en els aquàtics, i sovint la seva correcta elecció, ha estat considerada com un dels problemes més importants en ecologia. Aquesta consideració està basada en el fet que els paràmetres que condicionen als organismes poden variar segons l'escala d'observació, i per tant els patrons i processos existents també. Paral·lelament a això, i malgrat que s'hi puguin trobar controvèrsies en la literatura, aquests patrons i processos poden estar també influenciats segons el nivell d'organització o el nivell taxonòmic seleccionat. Per tot això, el treball que presentem aquí pretén estudiar els ecosistemes aquàtics de clima mediterrani a diferent escales i nivells d'organització de la comunitat de macroinvertebrats.

El clima mediterrani en el món

El clima mediterrani es caracteritza per presentar una elevada estacionalitat anual amb hiverns humits i freds, i estius secs i calorosos. De manera general, dos paràmetres defineixen bé el clima mediterrani: una precipitació que té lloc majoritàriament a l'hivern (malgrat que en algunes zones el període humit s'estén des de la tardor a la primavera) que molts autors fixen en més del 65% de la pluja anual, i la presència d'una sequera estival de longitud i intensitat variables. Les precipitacions mitjanes anuals varien entre 275 i 900 mm/a, encara que aquest rang no sempre és tan delimitat, i fins i tot, a vegades, algunes definicions de clima mediterrani exclouen el màxim de precipitació anual.

Hi ha cinc regions en el món que presenten un patró climàtic típicament mediterrani. Aquests regions mediterrànies[1], ubicades a l'oest dels continents entre 32º i 40º N i S, són la conca Mediterrània, Califòrnia, Xile, Sud-àfrica i Austràlia (el sud i el sud oest). Totes elles ocupen entre un 1 i un 4% de la superfície de la terra segons diferents autors, el que posa de manifest l'existència de nombroses discrepàncies en la delimitació i extensió de les àrees mediterrànies, degut a la presència de nombrosos microclimes inclosos dins el pròpiament anomenat clima mediterrani. En general però, la major part d'estudis coincideixen en l'existència de nombroses convergències entre les biotes de les regions mediterrànies, com a conseqüència de l'estacionalitat del clima mediterrani. Si bé les primeres comparacions entre comunitats biològiques de les regions mediterrànies es basen en estudis florístics, avui dia s'incideix també en la presència de nombroses convergències tant en comunitats d'invertebrats com de vertebrats. La majoria d'aquestes convergències han estat relacionades amb l'elevat estrès hídric estacional propi del clima mediterrani, que suposa l'existència d'adaptacions específiques de tipus fisiològic, morfològic i de comportament. En aquest sentit, la resiliència i la resistència són atributs comuns en la biota mediterrània. A més a més, les regions mediterrànies es caracteritzen per presentar una elevada diversitat biològica, factor que ha estat relacionat en nombroses ocasions amb l'elevada heterogeneïtat temporal (depenent del clima) i espaial (independent del clima).

Els rius mediterranis

Entenem per rius mediterranis aquells rius influenciats pel clima mediterrani, és a dir afectats per una heterogeneïtat estacional en el règim de precipitació i temperatures. De la mateixa manera que dins el clima mediterrani s'han distingit diversos microclimes segons l'orografia, l'altitud, les influències oceàniques o continentals,..., també es poden establir diverses tipologies de rius. D'aquesta manera, els rius de clima mediterrani poden presentar des de rius permanents d'origen nival, fins a rambles ubicades en les zones més àrides. En general però, els rius mediterranis es caracteritzen per una variació anual i interannual en el règim de cabals (d'amplitud variable) amb avingudes i sequeres anuals. En aquest sentit, els rius mediterranis estan sotmesos a dues pertorbacions anuals previsibles (malgrat que d'intensitat i freqüència imprevisibles) que suposen la presència de rius permanents i temporals (incloent els intermitents i els efímers). Nombrosos estudis indiquen l'elevada adaptació dels organismes aquàtics davant d'ambdues pertorbacions, el que suposaria trobar nombroses convergències

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[1] El terme mediterrani s'escriurà amb majúscula (Mediterrani) quan faci referència a la conca Mediterrània pròpiament dita, mentre que s'escriurà en minúscula quan es refereixi a les regions climàtiques.

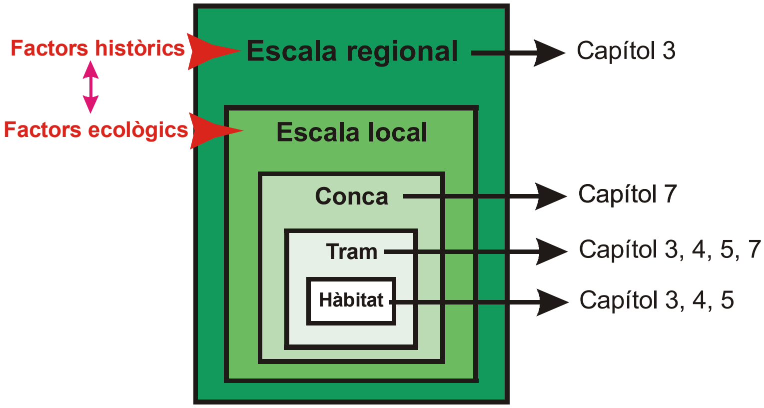
en els patrons i les respostes de les comunitats dels rius mediterranis. No obstant, òbviament, la temporalitat suposa un major greuge per la comunitat de macroinvertebrats que les avingudes, i per tant, són més interessants per determinar les respostes dels organismes en aquests sistemes. L'efecte de les sequeres en els rius mediterranis implica una reestructuració de la comunitat de macroinvertebrats, atès que l'hàbitat es veu enormement afectat amb la pèrdua, en primer lloc, de les zones ràpides, i en últim terme, de les lentes.

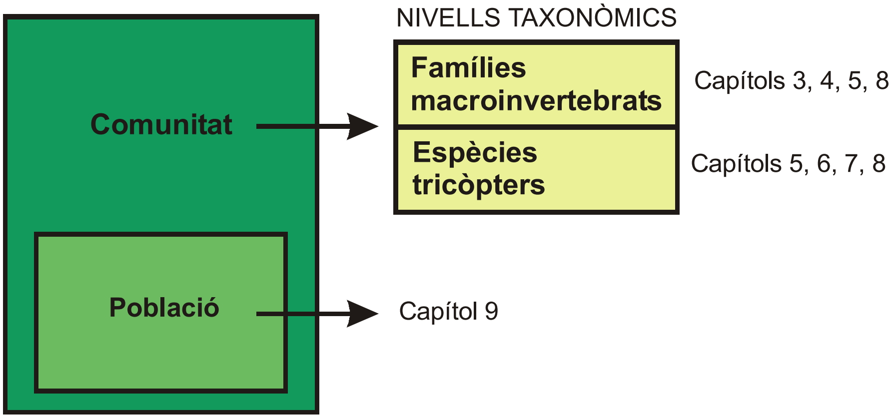
A més d'aquestes pertorbacions naturals, els rius mediterranis estan sotmesos a nombroses afeccions humanes, que alteren greument les comunitats d'organismes. D'aquesta manera, alguns autors han considerat que enlloc al món, la fauna aquàtica està davallant tant ràpidament com ho fa a les regions mediterrànies, degut a les nombroses introduccions d'espècies, a l'elevada densitat de població, a la manca d'aigua i a la seva mala gestió.

OBJECTIUS I ESTRUCTURA DE LA TESI

L'objectiu general d'aquest treball ha estat determinar els patrons i les respostes de les comunitats dels macroinvertebrats dels rius mediterranis a diferents escales, agrupades de manera general en regional i local (veure figura adjunta). S'entén com a escala regional, aquella relacionada amb factors històrics que hagin tingut lloc en regions grans, permetent la presència d'uns determinats taxons, però no d'uns altres. Per altra banda, entenem per escala local, aquella que està determinada, majoritàriament, per factors ecològics que permetin la presència d'uns organismes, en lloc d'uns altres, en unes determinades condicions ambientals, i dins d'una mateixa regió. Com que els rius estan organitzats jeràrquicament, hi ha nombroses escales que poden definir-se dins l'escala local. D'aquestes, ens centrarem en tres: la conca, el tram (diferències entre capçaleres, trams mitjos i baixos; diferències entre trams permanents i temporals) i l'hàbitat. Juntament amb l'estudi de les comunitats de macroinvertebrats a diferents escales espacials, l'escala temporal també s'ha tingut en compte en algunes ocasions, encara que s'ha tractat menys extensivament.

A més a més, la tesi se centra en l'estudi de la comunitat de macroinvertebrats a dos nivells organitzatius (comunitat i població) i taxonòmics (família i espècie). Per l'estudi de les poblacions i les espècies s'ha utilitzat els tricòpters, atès que es tracta d'un grup poc conegut en algunes de les zones estudiades, la qual cosa permetrà també, aportar informació faunística i ecològica rellevant per a posteriors treballs.


ESCALES


NIVELLS D'ORGANITZACIÓ

El treball s'agrupa en 9 capítols cadascun dels quals conté: la introducció, la metodologia, els resultats, la discussió i les referències. El conjunt de capítols es divideix en tres grups: 2 de metodologia, 3 de comunitats de macroinvertebrats a nivell de família i 4 que fan referència a les comunitats de tricòpters dels rius mediterranis. En aquest resum per a cada capítol presentem els objectius, els resultats obtinguts i les conclusions d'una manera sintètica.

Els objectius concrets de la tesi han estat:

Metodològics

- Establir una metodologia per a mostrejar les comunitats de macroinvertebrats dels rius mediterranis (Capítol 1).
- Avaluar l'aplicació d'aquesta metodologia en altres regions mediterrànies del món (Capítol 2).

A escala regional

- Estudiar l'estructura de la comunitat de macroinvertebrats en les diferents regions mediterrànies del món (Capítol 3).
- Establir convergències i divergències entre les regions mediterrànies, pel que fa a l'estructura (Capítol 3).

A escala local

- Determinar l'efecte de la temporalitat i l'hàbitat sobre la comunitat de macroinvertebrats de les regions mediterrànies del món, en condicions de referència (Capítol 3).
- Establir convergències i divergències entre aquestes regions, pel que fa a les respostes a aquests aspectes (Capítol 3).
- Estudiar l'efecte de la temporalitat sobre la reducció de l'hàbitat sobre les famílies de macroinvertebrats, en condicions de referència (Capítol 4).
- Estudiar com un determinat hàbitat influeix en la temporalitat o la permanència d'un tram de riu, i les implicacions que això té sobre la comunitat de macroinvertebrats (Capítol 5).
- Estudiar les comunitats de tricòpters de rius mediterranis (Capítol 6).
- Determinar els patrons de distribució espacials i estacionals de les comunitats de tricòpters i els factors ecològics que les afecten, en condicions de referència i no referència (Capítol 7).
- Determinar la resposta de les comunitats de tricòpters a la contaminació, a diferents nivells taxonòmics (família i espècie) (Capítol 8).
- Analitzar les asimetries fluctuants d'alguns paràmetres morfològics larvaris de vàries poblacions d'*Hydropsyche exocellata*, i relacionar-les amb les variables ambientals (Capítol 9).

METODOLOGIA

CAPÍTOL 1: Un protocol de mostreig per determinar l'estat ecològic dels rius i rieres de la zona Mediterrània espanyola.

La tesi que presentem aquí s'emmarca dins el Projecte GUADALMED, basat en la determinació de l'*estat ecològic* de 12 conques mediterrànies del llevant peninsular i les Illes Balears, segons les directrius expressades en la Directiva Marc de l'Aigua (veure Capítol 1, Introducció). Un dels objectius bàsics d'aquest projecte és l'establiment d'un protocol de mostreig que, d'una manera ràpida i eficaç, serveixi per a determinar l'estat ecològic dels rius (el que en termes anglosaxons s'anomena "Rapid Bioassessment Protocols") però, que al mateix temps, també permeti l'obtenció i l'ús de les dades, per estudiar els patrons de distribució dels macroinvertebrats. Per a tal fi, s'ha dut a terme un exercici previ d'intercalibració en un riu Mediterrani de la conca del Segura (veure Capítol 1, Metodologia). Per a dur a terme l'estudi de la qualitat del bosc de ribera, es va aplicar l'índex QBR per cada membre del projecte i els resultats varen ser comparats. Per l'estudi dels macroinvertebrats es varen comparar dos protocols, el Protocol 1 i el 2. El Protocol 1 està basat en una identificació en el camp de les mostres recol·lectades, mentre que en el Protocol 2 es separaren i s'identifiquen en el laboratori. A més a més, pel Protocol 2 es va analitzar el número mínim d'individus que calia comptar per a obtenir un índex biològic representatiu de tota la mostra. Els índexs biològics usats varen ser el IBMWP i el FBILL. La manera de capturar els organismes aquàtics i els aparells utilitzats han estat equivalents en els dos protocols.

OBJECTIUS Capítol 1

Establir el Protocol més escaient per la determinació de l'estat ecològic que permeti l'obtenció de dades útils per a dur a terme estudis més detallats de la comunitat de macroinvertebrats.

RESULTATS Capítol 1

Les comparacions entre els Protocol 1 i el 2 indiquen que ambdós són adequats per obtenir un valor de l'índex IBMWP o FBILL representatiu de la zona mostrejada. No obstant, i depenent dels objectius de l'estudi, la utilització del Protocol 2 permet la obtenció d'una major aproximació en l'estructura de la comunitat, atès que inclou mesures d'abundància més exactes i recull taxons rars. Així doncs, en estudis on s'usin comunitats de referència (caracteritzades per presentar una elevada diversitat de macroinvertebrats) seria més apropiat l'ús del Protocol 2. No obstant, malgrat que el Protocol 2 suposa un major esforç en el processat de la mostra, aquest podria ser simplificat només comptant 200 individus a l'atzar, ja que a partir d'aquí els rangs dels índexs biològics es mantenen.

CONCLUSIONS Capítol 1

Degut a les poques diferències observades entre mostrejadors, les dades del projecte obtingudes en cadascuna de les conques Mediterrànies podran ser comparades. Els resultats obtinguts de l'aplicació dels Protocols 1 i 2 podran ser comparats, malgrat que es recomana l'ús del Protocol 2 en funció dels objectius de l'estiu.

CAPÍTOL 2: Comparació de metodologies de mostreig per determinar la qualitat biològica en dues àrees de clima mediterrani

Varis mètodes de mostreig són utilitzats arreu per determinar la qualitat biològica dels ecosistemes aquàtics. Sovint aquests mètodes s'han establert prenent com a referència protocols desenvolupats en altres països, on s'han obtingut resultats eficaços, i adequant-los a cada regió. No obstant, poques vegades, un mètode ben establert en una regió, ha estat comparat amb altres mètodes que aporten resultats satisfactoris en regions diferents. Malgrat que algunes convergències són presents entre les diferents regions mediterrànies, alguns factors locals com els microclimes, la geologia el substrat, són els responsables de les divergències en les comunitats de les regions mediterrànies (veure Capítol 3). Per tant, una metodologia desenvolupada en una regió (com la del Capítol 1) podria o no aportar resultats satisfactoris en una altra, i per tant , els estudis sobre convergències o divergències entre regions no serien aplicables.

OBJECTIUS Capítol 2

Comprovar la viabilitat de l'aplicació de dues metodologies de mostreig multihàbitat utilitzades a Sud-àfrica (l'índex SASS5) i a la conca Mediterrània (l'índex IBMWP), a ambdues regions al mateix temps. Com que l'índex SASS5 està dissenyat per ser aplicat en el camp, la seva metodologia ha estat comparada amb el Protocol 1 del

Capítol 1. De manera general, les diferències entre les dues metodologies rauen en els hàbitats mostrejats (per al IBMWP mostregem les zones reòfiles separadament de les lenítiques, i per al SASS5 es mostregen les pedres separadament de la vegetació), la llum de malla de la xarxa utilitzada i l'esforç de recol·lecció i identificació en el camp.

RESULTATS Capítol 2

Ambdues metodologies han obtingut una elevada similitud en el número i el tipus de taxons recol·lectats, tan a Sud-àfrica com a la conca Mediterrània (més d'un 68% de similitud). A més a més, els dos protocols discriminen bé les capçaleres dels trams mitjos dels rius, i les localitats pristines de les lleugerament contaminades. Les comunitats de macroinvertebrats obtingudes de l'hàbitat reòfil i el lèntic del IBMWP han estat similars a les obtingudes de les pedres i a la vegetació en el SASS5, respectivament. En general, tan el mostrejador estranger con el natiu han trobat les mateixes famílies de macroinvertebrats quan han mostrejat en una o altra regió.

CONCLUSIONS Capítol 2

Tant el protocol SASS5 com el IBMWP han obtingut resultats similars pel que fa al nombre de famílies recol·lectades, a la composició de les comunitats i als valors obtinguts dels índexs biològics. Conseqüentment, els mètodes desenvolupats a la zona Mediterrània Ibèrica (Capítol 1) poden ser aplicats satisfactòriament en altres regions mediterrànies. Aquestes conclusions, permeten acceptar el fet que els resultats obtinguts dels mostreigs duts a terme en les diferents regions mediterrànies, puguin ser comparables, ja que reflecteixen de manera adequada la composició de les comunitats.

RESULTATS

COMUNITATS DE MACROINVERTEBRATS — ESCALA REGIONAL

El fet d'establir convergències i divergències entre regions desconnectades és la peça clau per a determinar l'aplicació dels principis ecològics derivats d'estudis locals en una altra àrea. Malgrat que en les regions mediterrànies els estudis locals sobre macroinvertebrats són nombrosos, molt pocs tracten de buscar similituds o diferències amb patrons que tenen lloc en altres regions del mateix clima.

El clima mediterrani va ser originat a finals de Pliocè, i per tant es tracta d'un clima jove en termes geològics. Malgrat que molta de la biota existent en aquestes regions va ser originada molt abans, amb l'establiment del clima les forces de selecció varen actuar de manera similar a totes les àrees, configurant la biota mediterrània actual. Conseqüentment, a l'hora d'establir convergències i divergències entre regions mediterrànies els factors històrics (independents del clima) i els factors ambientals (dependents o no del clima) han de ser considerats. D'aquesta manera es poden establir les similituds i les diferències en l'estructura i les respostes de les comunitats als factors ambientals.

CAPÍTOL 3a: Rius de clima mediterrani al món: convergències i divergències entre regions: *Convergències i divergències en l'estructura de la comunitat de macroinvertebrats*

OBJECTIUS Capítol 3a

> Comparar la composició faunística a nivell de família entre les diferents regions mediterrànies, per tal de conèixer si les diferències degudes a raons històriques poden ser importants per entendre les diferències entre els patrons ecològics.

RESULTATS Capítol 3a

> S'han utilitzat un total de 212 famílies per a comparar l'estructura dels macroinvertebrats en els rius mediterranis del món. La major riquesa taxonòmica la trobem a la conca Mediterrània amb 125 famílies, seguida de Califòrnia i el sud d'Austràlia, Sud-àfrica, el sud-oest d'Austràlia i Xile. Les regions de l'Hemisferi nord apareixen altament convergents (94% de similitud) degut a una història biogeogràfica similar i a condicions locals. Sud-àfrica es presenta també propera a Califòrnia i a la

conca Mediterrània (65% de similitud) ateses les connexions històriques existents amb l'hemisferi nord que facilitaren l'intercanvi de taxons. No obstant, els factors locals semblen els responsables d'algunes de les divergències (per exemple, la baixa diversitat de mol·luscs per les aigües àcides i oligotròfiques d'aquestes zones). Els rius mediterranis de Xile, malgrat que presenten algunes connexions amb les regions de l'Hemisferi nord, presenten una comunitat molt pobre degut a factors locals. El sud i el sud-oest d'Austràlia, presenten una comunitat de macroinvertebrats molt diferenciada de la resta de les zones mediterrànies. En el sud-oest australià la comunitat està molt més empobrida en comparació amb la del sud, degut a factors històrics.

CONCLUSIONS Capítol 3a

Els factors històrics però també els locals, són els responsables de les convergències i divergències entre regions mediterrànies a escala regional (veure Figura 3 del Capítol 3). Califòrnia i la conca Mediterrània convergeixen tant per factors històrics com locals, mentre que les regions de l'Hemisferi sud divergeixen per factors històrics i locals.

COMUNITATS DE MACROINVERTEBRATS — ESCALA LOCAL

CAPÍTOL 3b: Rius de clima mediterrani al món: convergències i divergències entre regions: *Convergències i divergències en les respostes de la comunitat de macroinvertebrats a la temporalitat i a l'hàbitat*

OBJECTIUS Capítol 3b

Estudiar l'efecte de la temporalitat i les característiques de l'hàbitat (reòfil i lenític) en les comunitats de macroinvertebrats en les diferents regions mediterrànies, per tal d'establir convergències i divergències en les respostes a aquests factors. Determinar com la riquesa taxonòmica local es troba influenciada per la regional en les diferents regions mediterrànies.

RESULTATS Capítol 3b

Els resultats presentats corresponen als mostreigs realitzats utilitzant la metodologia exposada en el Capítol 1, a la conca Mediterrània, Califòrnia, Sud-âfrica i el Sud-oest d'austràlia. Pel que fa a la temporalitat, excepte pel Sud-oest Australià, els resultats mostren diferències significatives entre els rius permanents i temporals, pel que fa a la composició de la comunitat, però no a la riquesa de famílies. En general, s'observa que durant la primavera, els rius permanents de totes les regions mediterrànies presenten una comunitat pròpia de les zones ràpides (Efemeròpters, Plecòpters i Tricòpters), mentre que els temporals estan caracteritzats per macroinvertebrats associats a les zones lèntiques com els Odonats, Heteròpters i Coleòpters. Quan les convergències i les divergències en les respostes a la temporalitat són analitzades entre parells de regions, s'observa que Sud-âfrica i el Sud d'Austràlia presenten una elevada similitud en les respostes a la temporalitat (94.4%). En canvi, Califòrnia i la conca Mediterrània, malgrat compartir un elevat nombre de famílies, la seva resposta a la temporalitat és menys convergent. Finalment, quan la matriu de famílies comunes entre totes les regions mediterrànies és utilitzada, s'obté que les diferències entre regions són majors que les observades entre localitats permanents i temporals. Tot això suggereix que els factors locals que caracteritzen cada regió (per exemple el substrat al sud-oest australià, l'acidesa i oligotrofisme de Sud-âfrica i l'elevada diversitat de tipologies de rius presents en la conca mediterrània) juntament amb els factors històrics (molt importants al sud-oest australià), podrien ser els responsables d'aquestes diferents respostes observades entre les regions mediterrànies.

Referent a l'hàbitat, totes les regions mediterrànies presenten una comunitat significativament diferent de les zones reòfiles respecte de les lenítiques, tant pel que fa a la composició com a l'estructura. En canvi, el nombre de famílies es similar en ambdós hàbitats. Quan s'analitza la composició de la comunitat de macroinvertebrats en detall, i tal i com hauria d'esperar-se, s'obté que les comunitats reòfiles estan dominades per famílies d'efemeròpters, plecòpters i tricòpters, mentre que les lenítiques ho són per odonats, heteròpters i coleòpters, de manera similar en totes les regions. En aquest cas, s'observa una major similitud entre regions (un 80% per totes les comparacions) que l'obtinguda per la temporalitat. No obstant, quan s'estudia la comunitat comuna per a totes les regions, excepte Califòrnia i la conca Mediterrània, les diferències entre regions segueixen sent majors que les observades entre hàbitats.

Segons diversos autors, la relació entre la riquesa regional i la local, en un conjunt de zones, indiquen la importància relativa dels processos regionals i dels locals que influencien la riquesa local. Els resultats obtinguts mostren que la relació entre ambdues riqueses és positiva entre el sud-oest d'Austràlia, Sud-àfrica i Califòrnia, el que indicaria que en aquestes zones la riquesa local està condicionada per la regional. En canvi en la conca Mediterrània (i també en alguns casos a Sud-àfrica), la diversitat local també està influenciada per la regional, però al mateix temps per processos locals que la regulen.

CONCLUSIONS Capítol 3b

Les diferents regions mediterrànies convergeixen en respostes a la temporalitat i a l'hàbitat per uns determinats aspectes però no per altres, el que podria estar relacionat amb els factors locals. En general, a la primavera les respostes a la temporalitat són menys convergents que les degudes a l'hàbitat, fet que explicaria que l'hàbitat actua com a un filtre de la comunitat més diferenciador que no la temporalitat.

CAPÍTOL 4: Efectes de tres macrohàbitats diferents en la comunitat de macroinvertebrats en rius mediterranis.

L'hàbitat ha estat considerat com un factor important en la organització i la regulació de la biota. La seva heterogeneïtat ha estat relacionada amb l'existència de nombroses i variades estructures i respostes per part dels organismes, i de manera freqüent s'ha considerat com un dels factors implicats en la diversitat. De manera general, es pot considerar que el concepte d'hàbitat en els rius inclou dos components: un d'estàtic (corresponent al substrat) i un de dinàmic (corresponent al cabal). Atès que sovint s'ha considerat que les característiques hidràuliques són més importants per explicar els patrons espacials i temporals de les comunitats, diversos autors han dividit l'hàbitat fluvial en zones reòfiles (ràpids) i zones lenítiques (basses). No obstant, en rius amb elevades variacions de cabal anuals i interanuals, com en el cas dels mediterranis, en l'efecte de l'hàbitat sobre les comunitats també hauria de considerar-se el factor temporal o estacional, atès que aquest és, de manera natural, modificat pel règim d'avingudes i de sequeres. Així, per exemple, durant una sequera, l'alternança de ràpids-basses es veu alterada de manera seqüencial en el temps, per la pèrdua de les zones reòfiles, en primer lloc, la subseqüent aparició de basses desconnectades, i finalment, la desaparició d'aquestes. No obstant, i malgrat que aquest gradient temporal en les característiques espacials dels rius ha estat descrita per diversos autors, molt pocs han mostrat les respostes dels macroinvertebrats.

OBJECTIUS Capítol 4

Estudiar els canvis de la comunitat de macroinvertebrats i la riquesa taxonòmica en tres macrohàbitats: ràpids, basses amb connexió i basses lents desconnectats. Determinar si les zones lenítiques associades als ràpids actuen com a un hàbitat intermedi segons l'estructura de la comunitat.

RESULTATS Capítol 4

L'estudi es va realitzar a la regió mediterrània de Califòrnia, durant la primavera. Degut a les característiques locals de cada riu o localitat, com ara la presència d'una bona cobertura de ribera o el microclima local, els tres macrohàbitats a testar es poden presentar al mateix temps en una regió, fet que suposa que el factor temporal pugui ser testat amb un únic mostreig.

Els resultats mostraren que la riquesa taxonòmica dels trams de riu amb basses desconnectades era similar a la trobada en els ràpids i a les basses connectades per ràpids. No obstant, es va fer patent una davallada en la relació entre la proporció d'efemeròpters, plecòpters i tricòpters a mesura que la desconnexió amb els ràpids augmentava. De la mateixa manera, l'estructura de la comunitat presentava diferències entre els tres hàbitats, indicant un canvi successiu de comunitats entre els ambients ràpids i els lents desconnectats passant pels lents connectats als ràpids. En aquest últim hàbitat, es va trobar una barreja de les comunitats reòfiles i les pròpies de les bases isolades, malgrat que algunes famílies són al mateix temps, exclusives d'aquest hàbitat.

CONCLUSIONS Capítol 4

L'elevada riquesa taxonòmica trobada en les basses desconnectades, amb la presència d'alguns taxons exclusius d'aquest hàbitats indicaria que aquests macrohàbitats funcionen com a illes isolades, però no com a refugis de famílies reòfiles davant d'una sequera. Les zones lèntiques associades als ràpids, apareixen com un hàbitat de transició entre els ràpids i els lents isolats. D'aquesta manera es pot establir un gradient d'estacions i de comunitats entre els ràpids més ben diferenciats cap als lents isolats, el que és congruent amb l'estructura de la comunitat però no amb el número de taxons. Al mateix temps, al llarg d'aquest gradient s'observa un increment en la variabilitat de les comunitats de macroinvertebrats en els punts, el que podria estar relacionat amb el temps en què un hàbitat lent isolat funciona com a tal.

CAPÍTOL 5: Heterogeneïtat espacial i temporal en la riquesa de la comunitat i les estratègies biològiques en un sistema mediterrani temporal: relacions amb el "River Habitat Template".

En el Capítol anterior veiem com la temporalitat comporta una alteració de l'hàbitat que té conseqüències en les comunitats de macroinvertebrats. No obstant, malgrat que el clima mediterrani és, potser, un dels factors més importants a l'hora de determinar si un riu en un any concret serà o no temporal, altres factors poden estar-hi relacionats, com per exemple, les característiques de l'hàbitat. Per tal d'establir aquesta relació, l'heterogeneïtat de l'hàbitat fluvial ha de ser quantificada i comparada amb el grau de temporalitat de les estacions analitzades.

Els ecosistemes són heterogenis en l'espai i el temps. Varis factors han estat relacionats amb aquesta heterogeneïtat, com ara els abiòtics, els biòtics o les pertorbacions humanes i naturals. La teoria de l'"Habitat Template" està basada en la idea de què l'hàbitat és un marc on l'evolució determina estratègies biològiques adaptades. En la seva aplicació en els sistemes aquàtics, l'"Habitat Template" estableix un espai dimensional constituït per l'heterogeneïtat temporal i l'espacial, en el qual diferents estratègies biològiques hi estan associades.

Depenent del grau de temporalitat, els rius es poden classificar en permanents (l'aigua flueix tot l'any), intermitents (l'aigua roman en basses desconnectades a l'estiu) o efímers (el riu flueix uns pocs mesos a l'any només després de pluges importants). Conseqüentment, l'heterogeneïtat temporal augmenta dels rius permanents als efímers.

OBJECTIUS Capítol 5

Determinar l'heterogeneïtat espacial en la composició de l'hàbitat i examinar com aquesta heterogeneïtat espacial afecta a l'heterogeneïtat temporal dels rius permanents, intermitents i efímers. Estudiar quina és la influència d'ambdues heterogeneïtats en la riquesa de macroinvertebrats i les seves estratègies biològiques.

RESULTATS Capítol 5

Per tal de quantificar si l'hàbitat afectava a la temporalitat, es varen formular les següents hipòtesis, segons les quals el riu seria més temporal si: (1) en el substrat dominen els sòcols de roca en lloc de les graves i els còdols, (2) les basses són més dominants que les zones ràpides, (3) si a l'hivern hi ha un elevat cabal i (4) si a l'estiu hi ha flux d'aigua. Aplicant aquests criteris, les localitats mostrejades es varen ordenar de més a menys permanència a menys permanència, i se'n va definir el RPS ("reach permanence score" o grau de permanència del riu) el qual es va comparar amb l'estat del riu observat a l'estiu. Segons els resultats obtinguts el RPS definit a partir del component físic de l'hàbitat està estretament relacionat amb el grau de temporalitat, distingint-se rius permanents, intermitents i efímers. En tots aquests rius existeix un canvi en la comunitat entre l'època humida (hivern) amb la seca (estiu), distingint-se tres grups de famílies: les reòfiles dominants a l'hivern, les lenítiques a l'estiu i les comunes.

No s'han trobat diferències significatives en la riquesa de macroinvertebrats entre els rius permanents i els intermitents, però sí en els efímers. Els resultats de l'anàlisi de les estratègies biològiques indiquen que aquestes eren diferents en els rius permanents, temporals i efímers. Així, en els intermitents les espècies presenten unes estratègies tipus K, associades als ambients de bassa. En canvi, en els permanents no es troba un patró clar de les estratègies dominants indicant l'existència d'una barreja d'estratègies. Finalment, en els rius efímers, les espècies dominants tenien estratègies tipus r, per la poca durada del medi.

CONCLUSIONS Capítol 5

L'hàbitat i la temporalitat poden ser interdependents. L'hàbitat pot canviar la temporalitat i la temporalitat fa canviar l'hàbitat. Els rius permanents posseeixen una elevada heterogeneïtat espacial fruit d'un hàbitat complex i una baixa heterogeneïtat temporal, atesa la seva poca variabilitat en el temps. Els rius intermitents tenen una heterogeneïtat espacial i temporal intermedia. Els cursos efímers tenen una elevada heterogeneïtat temporal però no espacial, la qual es manifesta en una riquesa de macroinvertebrats diferenciada de la dels trams permanents o intermitents. En tots els casos existeixen diferències entre les comunitats presents en l'època humida i la seca.

En l'aplicació del marc conceptual establert en el "River Habitat Template" als rius mediterranis s'aprecien diferències en les estratègies biològiques en el gradient permanent-efímer.

COMUNITATS DE TRICÒPTERS — ESCALA LOCAL

Tot i que nombrosos autors assenyalen que els patrons ecològics observats a nivell de família (tractat en els capítols anteriors) es corresponen bé amb els mostrats pels gèneres i les espècies, d'altres incideixen en el fet que sovint les espècies donen informació més precisa de la resposta de les comunitats davant factors externs. Aquest tema ha estat àmpliament debatut en el camp del biomonitoratge, i malgrat que no existeix un consens clar, en general s'entén que l'ús d'un o altre nivell taxonòmic dependrà dels objectius fixats en l'estudi.

Per determinar l'estructura i les respostes d'un nivell taxonòmic inferior al de família en els sistemes mediterranis s'ha utilitzat l'ordre dels tricòpters, atès que aquests organismes són un grup ideal degut a la seva diversificada adaptació als ecosistemes aquàtics

CAPÍTOL 6: Trichoptera (Insecta) de les conques Mediterrànies Ibèriques: notes taxonòmiques i requeriments ecològics.

És ben conegut que la fauna de la conca Mediterrània presenta una elevada diversitat i alt nombre d'espècies endèmiques, com a resultat de la interacció de complexos factors històrics i ecològics. En aquest sentit, a la Península Ibèrica, l'ordre dels tricòpters comprèn nombroses espècies (331), comparat amb zones més temperades. Els primers estudis de tricòpters a la Península Ibèrica daten de mitjans del segle XIX, malgrat que la major part dels treballs han estat fets més recentment. No obstant, existeix un coneixement diferencial de la fauna dels tricòpters, atès que la majoria d'estudis s'han dut a terme a la meitat nord de la Península. Els tricòpters de les conques Mediterrànies han estat poc estudiats, malgrat que es coneixia la presència de vàries espècies, gràcies a estudis ecològics realitzats en algunes conques, o a captures disperses realitzades per diversos autors.

Les larves de tricòpters recol·lectats en 11 conques Mediterrànies, incloses en el projecte GUADALMED, així com d'altres estudis realitzats principalment a la regió nord-est Peninsular, varen ser identificades al nivell taxonòmic més fiable. Atès que les dificultats per identificar larves són nombroses, sobretot per algunes famílies, el mostreig de les larves va estar acompanyat, quan va ser possible, tant per la recol·lecció d'adults, com de pupes. Les identificacions fetes a partir d'aquests estadis més tardans, són molt més fiables i ens ajuden a confirmar la presència de certes espècies, que a nivell larvari són dificultoses.

OBJECTIUS Capítol 6

Presentar un llistat faunístic de les espècies de tricòpters recol·lectades en el llevant Mediterrani peninsular, amb indicacions sobre la distribució i l'ecologia de les larves i dels adults. A més a més, mostrar les peculiaritats taxonòmiques d'algunes espècies. Finalment, determinar el percentatge d'espècies amb distribució europea, nord ibèrica-africana i endèmica pel conjunt de conques agrupades segons estiguin ubicades al nord, centre o sud de la Península Ibèrica.

RESULTATS Capítol 6

De les 12499 larves 177 pupes i 261 adults recol·lectats en 169 estacions de mostreig, 91 espècies han estat identificades. D'aquestes espècies cal destacar que es confirma la presència a la Península Ibèrica de *Glyphotaelius pellucidulus,* fins ara només coneguda a partir d'estadis larvaris. A més a més, es fan observacions taxonòmiques sobre espècies de larves que romanen sense descriure i s'aporten algunes evidències d'una possible espècie nova. Finalment, s'inclouen dades sobre els requeriments de les espècies que ajuden a afinar els rangs de tolerància i de distribució coneguts fins ara.

La majoria d'espècies presents en les conques del nord, centre i sud del Mediterrani Peninsular, presenten un distribució europea. S'observa, de nord a sud, una davallada en la proporció d'espècies europees i un increment en les endèmiques i les compartides amb nord Àfrica.

CONCLUSIONS Capítol 6

S'amplien les àrees de distribució d'algunes espècies, es confirma la presència d'altres i s'indiquen rellevants informacions taxonòmiques i ecològiques per a futurs estudis.

CAPÍTOL 7: Patrons de distribució dels tricòpters en els rius Mediterranis de la Península Ibèrica.

L'ecologia de les comunitats, i sovint també la biogeografia, estan interessades en detectar els patrons en les comunitats i en determinar-ne els factors responsables. Els ecòlegs, tradicionalment, s'han centrat en l'estudi de les forces abiòtiques i biòtiques, mentre que els biogeògrafs inclouen també els factors històrics, malgrat que sovint aquesta diferenciació no és fàcil. L'estudi dels patrons és altament depenent de l'escala, i s'entén, que els factors que controlen les distribucions dels organismes també ho són.

OBJECTIUS Capítol 7

Determinar els patrons de distribució i els factors ecològics implicats en la distribució dels tricòpters del llevant Peninsular.

RESULTATS Capítol 7

En el camp de la biogeografia, s'accepta que les àrees de distribució són heterogènies en l'espai i el temps. En els sistemes mediterranis, on els rius són molt variables en el temps i en l'espai, els patrons de les comunitats haurien de ser entesos en ambdós sentits. Així, en aquest Capítol s'han utilitzat les dades del projecte GUADALMED corresponents a quatre èpoques de l'any. Els resultats previs del capítol mostren que l'estacionalitat és rellevant per la comunitat de tricòpters diferenciant-se unes comunitats concretes en cada estació, malgrat que un conjunt d'espècies es trobin representades durant tot l'any. Els patrons espacials doncs, han estat analitzats extraient la variabilitat estacional.

La riquesa taxonòmica ha estat variable al llarg del Mediterrani, amb un màxim localitzat a la conca del Segura. D'entre els taxons representats, alguns s'ubiquen en totes les conques com ara *Hydroptila* sp. o *Hydropsyche* gr. *pellucidula*, però altres han estat recol·lectats, majoritàriament, a les conques del nord o del sud, sent el Segura la zona de transició. A més a més, també s'observen connexions entre les conques més ubicades al nord (Pirineus) i al sud (Sierra Nevada).

Quan la distribució dels tricòpters s'intenta explicar amb les variables ambientals mesurades, s'obtenen cinc grups de taxons associats a cinc tipus de rius: capçaleres calcàries, capçaleres silíciques, trams mitjos de rius sedimentaris i margosos, trams mitjos de rius calcaris i trams baixos de rius calcaris i sedimentaris. Aquests grups estan definits per una sèrie de factors ambientals: conductivitat, àrea de la conca, índex biològic, ordre del riu, característiques de l'hàbitat fluvial i del bosc de ribera, altitud, amplada del canal, i geologia, que actuen a diferents escales. Existeixen diferències significatives entre els tricòpters associats a cadascun d'aquests grups. Les comunitats de tricòpters trobades en les capçaleres calcàries i silíciques mostren una elevada convergència, malgrat que cada grup presenta vàries espècies exclusives.

Les variables ambientals més importants per explicar la distribució dels tricòpters són la geomorfologia seguides dels paràmetres fisico-químics. Malgrat que la temporalitat és un factor clau en els rius mediterranis, sembla poc important en la distribució dels tricòpters, encara que algunes espècies semblen estar-hi associades.

CONCLUSIONS Capítol 7

Els patrons observats en la distribució dels tricòpters són heterogenis en l'espai i en el temps, i els factors implicats són una barreja de variables que afecten a escala gran (de conca) i petita (de tram o de punt de mostreig). Les variables relacionades amb la zonació longitudinal i la geologia són les més significatives per explicar la distribució dels tricòpters. L'elevada riquesa observada a la conca del Segura, amb una barreja d'espècies de conques àmpliament distribuïdes al nord amb d'altres del sud, podria estar relacionada amb factors històrics. Tot això, indicaria que una barreja de factors locals i històrics podria explicar la distribució dels tricòpters.

CAPÍTOL 8: Òptims i perfils ecològics dels tricòpters en els rius Mediterranis.

En el capítol anterior s'ha demostrat que la distribució dels tricòpters en els rius Mediterranis està altament influenciada per variables morfològiques i poc per variables de qualitat. No obstant, això no significa que aquests organismes no estiguin afectats per la contaminació. De fet, per la seva elevada sensibilitat a la contaminació, els tricòpters han estat utilitzats en nombroses ocasions com a marcadors de la qualitat de l'aigua. Així, han estat inclosos a nivell d'ordre en alguns protocols multimètrics o utilitzats en els índexs biològics a nivell de família o d'espècie. Sovint molts d'aquests índexs s'han desenvolupat tenint en compte les toleràncies ambientals de les famílies i les espècies. No obstant, però, els valors de tolerància de les espècies s'han obtingut mitjançant observacions al camp, sense estudis específics que avaluessin la seva validesa.

Si bé fins ara els factors de temporalitat i hàbitat han estat clau per explicar alguns els patrons de les comunitats de macroinvertebrats, en el present capítol ens centrarem en l'efecte de la contaminació sobre les comunitats de tricòpters.

OBJECTIUS Capítol 8

Determinar els efectes de la contaminació en la comunitat de tricòpters a nivell de família i espècie (o gènere en alguns casos), establint toleràncies ambientals a una sèrie de variables químiques i biològiques mesurades.

RESULTATS Capítol 8

Els òptims i la tolerància de les famílies i espècies de tricòpters han estat establerts per les següents variables: IBMWP, QBR, oxigen, amoni, nitrits, fosfats, sulfats, clorurs, sòlids en suspensió i conductivitat. Els valors d'òptims i toleràncies obtinguts mostren que diferents taxons estan afectats de diferent manera per cadascuna de les variables utilitzades. No obstant, en general s'observa que a nivell de família els Glossosomatidae (considerats comunament com a indicadors de bona qualitat), els Hydroptilidae i Hydropsychidae presenten òptims a valors baixos dels índexs biològics i de ribera i a elevades concentracions dels paràmetres químics. En canvi, famílies com Brachycentridae, Sericostomatidae, Lepidostomatidae o Odontoceridae apareixen molt sensibles a la contaminació. A nivell d'espècie s'observen toleràncies ecològiques similars a les observades amb les famílies, quan la família conté poques espècies o és molt sensible a la contaminació. En canvi, en altres casos (com per exemple succeeix amb els Hydropsychidae), les toleràncies observades a nivell de família són molt diferents de les que obtingudes de les espècies.

Quan totes les variables ambientals es representen per cadascun dels taxons, s'obtenen els perfils ecològics. Atès que les variables ambientals mesurades afecten de manera diferent a cada família o espècie, aquests perfils ens ajuden a entendre, d'una manera global, la tolerància o la sensibilitat de cada taxó a la contaminació. Dels resultats d'aquests perfils ecològics hem establert un índex que indica el grau d'intolerància d'un taxó a la contaminació, anomenat DIS ("Degree of Intolerance Score"), el que podria ser la base d'un índex biològic a nivell d'espècie similars als utilitzats en altres països. Quan el DIS, a nivell de família, es compara amb els valors d'intolerància establerts en el IBMWP, s'observa que en general hi ha un bon ajust. No obstant, en alguns casos com en els Glossosomatidae, el valor obtingut a nivell de família amb el DIS és molt menor al nivell de tolerància indicat en el IBMWP, el que està relacionat amb que algunes espècies d'aquesta família són capaces de tolerar elevades salinitats (probablement d'origen natural) i certa contaminació per amoni, però d'altres no.

CONCLUSIONS Capítol 8

Diferents variables indicadores de contaminació afecten, de manera diferent, a les famílies i espècies de tricòpters. Els patrons observats per les famílies i les espècies són similars en alguns casos però diferents en altres, el que està relacionat amb la diversitat específica i el grau d'intolerància. L'obtenció d'un índex que mesuri el grau d'intolerància de les famílies i espècies podria ser la base per l'establiment d'un índex biològic basat en tricòpters. Les toleràncies de les famílies expressades a l'índex IBMWP en general s'ajusten bé a les toleràncies ambientals trobades.

POBLACIONS DE TRICÒPTERS — ESCALA LOCAL

CAPÍTOL 9: Relació entre la contaminació i l'asimetria fluctuant de les larves del tricòpter tolerant **H. exocellata** *(Trichoptera, Insecta)*

En el capítol anterior, la relació entre els tricòpters i la contaminació s'ha tractat des del punt de vista de la família i de l'espècie. Malgrat que nombrosos estudis han mostrat que els tricòpters són uns bons indicadors de la qualitat de l'aigua a nivell d'espècie i família, utilitzant tan larves com adults, menys freqüent han estat l'ús de paràmetres poblacionals dels tricòpters per expressar la contaminació de l'aigua. D'aquests, cal destacar els estudis de deformitats morfològiques, canvis en patrons de coloració, testos de toxicitat i, més recentment, asimetries en paràmetres morfològics. Els estudis que analitzen els efectes de la contaminació sobre els individus són interessants atès que aporten informació sobre el grau d'afecció de la contaminació sobre l'espècie estudiada, i per tant poden ser vitals per prevenir la seva desaparició en condicions més desfavorables.

Nombrosos estudis reforcen la idea que l'estrès ambiental que una espècie pateix durant el desenvolupament, es tradueix en asimetries morfològiques que poden afectar a varis paràmetres. De les tres asimetries que es coneixen, la fluctuant sembla ser la que està més relacionada directament amb l'estrès (encara que no és l'única), i per tant ha estat considerada com a una indicadora de la qualitat ambiental. Així, els estudis que relacionen la qualitat de l'aigua amb els nivells d'asimetria dels macroinvertebrats estan augmentant darrerament. No obstant, la majoria d'aquests treballs estan basats en l'anàlisi de pocs paràmetres morfològics que, a l'hora, es relacionen amb poques variables indicadores d'estrès ambiental.

OBJECTIUS Capítol 9

> Determinar els nivells d'asimetria en les larves d'*Hydropsyche exocellata,* en diversos punts del tram mig i baix del riu Llobregat. Relacionar aquests nivells d'asimetria amb la qualitat química de l'aigua mesurada al Llobregat.

RESULTATS Capítol 9

> Es varen mesurar 20 caràcters morfològics de les larves d'*H. exocellata,* dels quals només dos varen ser eliminats degut a l'elevat error de mesura que mostraven. Dels restants, tots, excepte la longitud de la mandíbula, varen mostrar la presència

d'asimetria fluctuant i, per tant, varen ser relacionats amb la qualitat ambiental. Els nivells d'asimetria augmenten riu avall del Llobregat, però amb intensitat del caràcter utilitzat. A més a més, l'efecte de la contaminació és també diferent en funció del caràcter analitzat. En general però, la salinitat (clorurs i conductivitat) i, en alguns casos els fosfats han estat les variables més correlacionades amb l'asimetria.

CONCLUSIONS Capítol 9

Hi ha una estreta relació entre els nivells de contaminació del riu Llobregat i l'augment de l'asimetria fluctuant per a tots els paràmetres mesurats. No totes les variables químiques utilitzades es relacionen amb l'asimetria fluctuant. Així, la contaminació per sals i fosfats semblen ser les variables més implicades, encara que la seva influència no és equivalent en totes les variables morfològiques.

Brief introduction and objectives

INTRODUCTION

In all ecosystems, patterns and processes are highly influenced by spatial and temporal scales, and the organization level used. The scale effect over communities has been widely discussed either, in terrestrial and aquatic ecosystems. Very often, the choice of the correct scale has been considered the main problem in ecology. This phenomenon is based on the idea that the factors affecting communities can vary depending on the observation scale, and therefore, patterns and processes do as well. Similarly, although several controversies can be found in literature, patterns and processes can also be influenced by the organization and taxonomical level used. The work we present here try to study macroinvertebrates from mediterranean aquatic ecosystems at different scales, organization and taxonomical levels.

The mediterranean climate

Mediterranean climate is characterized by a high seasonality with wet and cold winters and dry and hot summers. Overall, two factors can be used to define mediterranean climate: over 65% of the annual precipitation falling in winter (although in some areas the wet period goes from autumn to spring), and the presence of a summer drought with length and intensity variables. The mean annual precipitation varies between 275-900 mm/a, although sometimes this is not as fixed, and some definitions exclude the maximum level of annual precipitation.

There are five regions in the world that present a typical mediterranean climate, called mediterranean regions[1]: Mediterranean Basin, California, Chile, South Africa and south and southwestern Australia. They are located in the west side of the continents between 32º and 40º N and S. The extension of the mediterranean area is between 1-4 % of the earth surface according to different authors, what demonstrates the numerous discrepancies in its delimitation because several subclimates can be established. However, numerous studies agree with the presence of several convergences in biota between mediterranean regions, as a consequence of the seasonality of the climate. Although most of these studies are focused in plant communities, nowadays the comparisons between invertebrates and vertebrates are increasing. Most of these convergences have been related with a high seasonal water stress enhancing the presence of several specific physiological, morphological and behavioral adaptations. In that sense, resilience and resistance are common attributes in mediterranean biota. Moreover, mediterranean regions are characterized by a high biological diversity, what has been related with the high temporal (dependent on the climate) and spatial (independent on the climate) heterogeneity.

Mediterranean rivers

We have considered mediterranean rivers as those influenced by mediterranean climate (i.e., affected by a seasonal heterogeneity in the precipitation and temperature regimes). As several subclimates can be distinguished in the mediterranean climate, according to the orography, altitude, oceanic influences… several river typologies can be distinguish in mediterranean rivers. Thus, mediterranean rivers could include from permanent rivers with snowy influence until "ramblas" in arider areas. Overall, mediterranean rivers are characterized by an annual and interannual discharge regime with annual floods and droughts. In that sense, mediterranean rivers are subjected to two annual predictable perturbations (but with intensity and frequency impredictable) implying the presence of permanent and temporary rivers (including intermittent and ephemeral ones). Several studies have demonstrated the numerous adaptations of aquatic organisms to floods and droughts, what would imply several convergences in patterns and responses of organisms in mediterranean rivers around the world. However, temporality is a most dramatic factor to the community than floods, and thereby it is much more interesting to study convergences and divergences between regions,

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[1] Mediterranean is written with "M" when is referred to the Mediterranean Basin, and with "m" when it speaks about the climate.

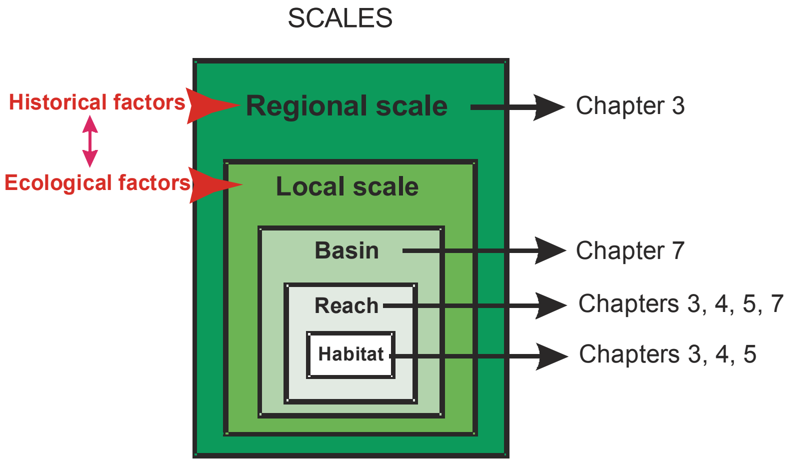
The drought effects on the mediterranean river imply a community reorganization of macroinvertebrate communities, as the habitat is highly modified firstly by the lost of riffles and finally by the lost of pools.

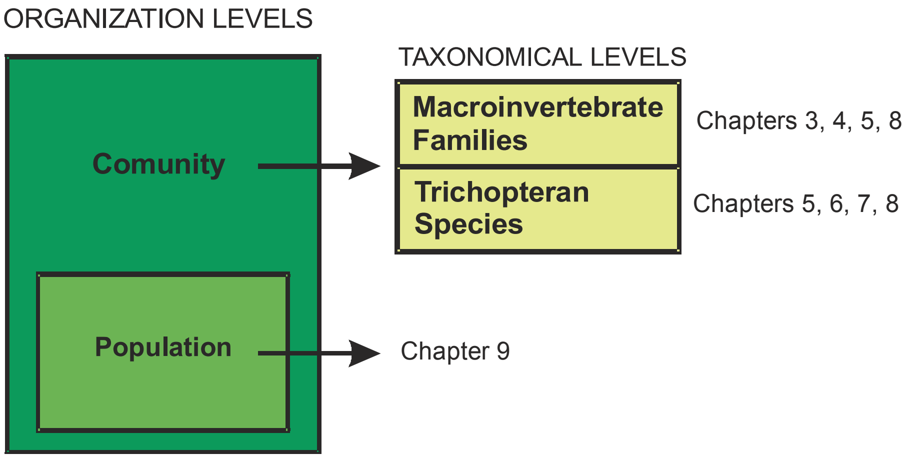
Despite of these natural perturbations, mediterranean rivers are subjected to numerous human alterations, affecting aquatic communities. In that sense, some authors have been considered that nowhere else in the world aquatic fauna is declining as rapidly than in mediterranean regions because of non-native introductions, high population density, limited availability of water and unsatisfactory management.

STRUCTURE AND OBJECTIVES

The general objective of this work is to determine patterns and responses of macroinvertebrates in mediterranean rivers at different scales, grouped in regional and local ones (see attached figure). Regional scale is understood here, as the one related to historical factors occurring in large regions, allowing the presence of several taxa but no others. On the other hand, local scale is referred to the one mainly determined by ecological factors allowing the presence of organisms in specific environmental conditions inside a region. As the rivers are organized hierarchically there are several scales included in the local one. From those, we have focused our work in three: basin, reach (differences between headwaters, midstreams and lowland reaches; differences between permanent and temporary reaches) and habitat. Jointly with the study of the macroinvertebrate communities at different spatial scales, temporal scale has been also included in some cases, but less frequently.

Moreover, the present work is focused in the study of the macroinvertebrates at different organization levels (community and population) including different taxonomical levels (family and species). For analysis populations and species, Trichoptera has been selected because its relatively poorly known groups in the studied areas, what at the same time will provided faunistic and ecological information outstanding for future studies.





The present study comprises 9 chapters. Each one included an introduction, methodology, results, discussion and references. The chapters can be grouped in three groups: 2 methodological, 3 of macroinvertebrate communities at family level, and 4 of caddisfly communities at family, species and population levels.

The specific objectives of the study are:

Methodological

- To establish a methodology for sampling macroinvertebrate communities in mediterranean rivers (Chapter 1).
- To evaluate the applicability of this methodology in other mediterranean regions in the world (Chapter 2).

Regional scale

- To study the macroinvertebrate structure in the mediterranean regions of the world (Chapter 3).
- To establish convergences and divergences between mediterranean regions according to its structure (Chapter 3).

Local scale

- To determine the effects of temporality and habitat over the macroinvertebrate community in mediterranean regions of the world in reference conditions (Chapter 3).
- To establish convergences and divergences between mediterranean regions according to their responses to temporality and habitat (Chapter 3).
- To study the effect of the temporality over the habitat reduction and its influence on macroinvertebrate communities in reference conditions (Chapter 4).
- To study how a specific habitat determines temporality or permanency of a reach and its effects on macroinvertebrate communities in reference conditions (Chapter 5).
- To study the caddisfly communities in Spanish mediterranean rivers (Chapter 6).
- To determine the spatial and seasonal distribution patterns of caddisfly communities and the ecological factors implied in reference and non-reference conditions (Chapter 7).
- To determine the response of caddisfly communities to pollution at different taxonomical levels (families and species) (Chapter 8).
- To analyze the fluctuating asymmetry of some morphological traits in several larval populations of *Hydropsyche exocellata*, and relate it with environmental variables (Chapter 9).

Chapter 1

A SAMPLING PROTOCOL TO ASSESS THE ECOLOGICAL STATUS OF STREAMS AND RIVERS IN THE SPANISH MEDITERRANEAN AREA

INTRODUCTION

The Water Framework Directive (WFD) (European Parliament and Council, 2000) requires that the European countries need to assess the ecological status of their freshwater ecosystems using biological indicators (e.g. macroinvertebrates, fishes, macrophytes, riparian vegetation). Before 2016, the EU countries have to show to the Commission that their rivers and lakes are in a very good ecological status. In the United States, concepts as ecological health or biological integrity have been a key element for the water quality management and are included in environmental laws (Karr & Chu, 2000). As a consequence, there are several standardized methodologies to its assessment (Plafkin *et al.*, 1989; Barbour *et al.*, 1999; Carter & Resh, 2001). Similarly, in the last few years, some European countries have developed methodologies to assess the ecological status (Bloch, 1999; Chovanec *et al.*, 2000; Harper *et al.*, 2000). In Spain, despite the high number of studies about (and using) biological indices to establish river water quality (e.g., Alba-Tercedor *et al.*, 1992), there is not a standard methodology to be applied to water management.

To asses the river health status, different countries use Rapid Bioassessment Protocols (RBPs) (Wright *et al.*, 1984; Plafkin *et al.*, 1989; Davies, 1994; Tiller & Metzeling, 1998; Chutter, 1998; Barbour *et al.*, 1999). These methods are based in the evaluation of the biological integrity

(Karr, 1981, 1996) using habitat and biological quality assessment and a further comparison with the reference conditions (Barbour *et al.*, 1999; Resh *et al.*, 1995; Reynoldson *et al.*, 1997). The RBPs have been designed to be efficient, effective, easy to use, and low in cost and to be applied in wide regions (Resh & Jackson, 1993; Resh *et al.*, 1995). All this properties derive in a simplified sampling and processing of the samples, avoiding as much as can be possible, and the loss of information (Resh *et al.*, 1995; Barbour & Gerritsen, 1996).

One way for simplifying and optimizing the sampling is decreasing the number of samples per site (Resh *et al.*, 1995; Hewlett, 2000), integrating all the communities from the different habitats (Stribling *et al.*, 1993; Resh *et al.*, 1995), or sampling the "most productive habitat" present (Plafkin *et al.*, 1989). This approach has statistical implications because the lack of replicates for a site eliminates several parametric statistical methods from being used in analysis (Hulbert, 1984; Norris, 1995). However, the use of reference sites as replicates could avoid this problem (Norris, 1995; Resh *et al.*, 1995).

The processing of samples is a key factor in the use of RBPs designed for macroinvertebrates. Tiller & Metzeling (1998) and Metzeling & Miller (2001) proposed to sample and process the sample in the field during 30 minutes until 200 individuals were obtained. Other methods are time independent and the samples are processed in the lab counting 200 individuals, after taking the largest animals (Plafkin *et al.*, 1989; Barbour *et al.*, 1999). Barbour & Gerritsen (1996) showed that using a fixed number of individuals, the distribution patterns are similar from the ones using all the individuals. However, this subsampling procedure based in a fixed number of individuals could have implications in assessing the water quality, because the frequency and abundance of the rare taxa are affected (Cao & Williams, 1999; Cao *et al.*, 2001) and because it means that the organisms should have a homogeneous distribution (Countermanch, 1996). Due to that, other authors prefer a subsampling based in a fixed fraction (Cuffney *et al.*, 1993; Vinson & Hawking, 1996; Countermanch, 1996).

The rivers in mediterranean areas are subjected to high natural flow variability that implies the temporality of most of the rivers and streams and allows the presence of seasonally different macroinvertebrate communities (e.g., Gasith & Resh, 1999). Moreover, the human impacts are large: waste, flow regulation, riparian alteration, habitat alteration… (Prat, 1994; Prat & Ward, 1994; Prat & Munné, 2000). Consequently, methodologies developed in other countries are not directly applicable in these environments. The GUADALMED Project (see Limnetica, in press for a detailed description) is a Spanish funded project (HID98-0323-C05) that attempts to assess the ecological status of the Mediterranean rivers and to establish the main factors implied on them. Six research teams belonging to different institutions in the country are implied: University of Barcelona, University of Vigo, University of Illes Balears, University of Murcia, University of Almeria, University of Granada and CEDEX. The main objective of the first stage of the GUADALMED Project was to establish, test and intercalibrate a standardized sampling Rapid Bioassessment Protocol to be adopted by the administration managers when the WFD is applied. The validation of the protocol is done under GUADALMED project for all the main watersheds draining into the Mediterranean sea in the Spanish coast (12 basins, 157 sites). In this paper we present data on the intercalibration exercise using macroinvertebrates.

The selection of a protocol to be used is based on the experience of the researchers of the project in the Iberian mediterranean rivers. Thus, for the biological quality establishment, two methodologies have been tested: IBMWP (Alba-Tercedor & Sánchez-Ortega, 1988; Alba-Tercedor, 1996; Alba-Tecedor & Pujante, 2000) and FBILL (Prat *et al.*, 1999); these two indices were chosen because they have been largely used in the area and proved to be sensitive to water quality. To evaluate the riparian vegetation status, the index QBR is used (Munné *et al.*, 1998; Suárez-Alonso & Vidal-Abarca, 2000; Munné *et al.*, in press).

METHODOLOGY

Study area

To select and intercalibrate the sampling and sorting methodology to be used in the project, we chosed a sampling site in the headwaters of the Argos stream (Barranda, Murcia), tributary of the Segura river (Figure 1). Argos stream is an intermittent stream with 48 km length, a slope of 18,6% and a drainage basin of 506 km^2. In the selected sampling site, the stream order is 4 and the altitude is 780 m. It’s a site with low eutrophication, with hyposaline, alkaline waters, well oxygenated and hard and neutral waters (Table 1, from Vidal-Abarca, 1985). The channel substrate is mostly made by gravel, although sand, cobbles and bedrock can be found. Algae are abundant and dominated by Oscillatoriales, Nostocales, Cladophorales, Charales and Zygnematales (Aboal, 1988, 1989). The sampling was carried out in February 1999, which usually is close to the end of the wet season in this Mediterranean climate area.

Figure 1. Segura basin and sampling site in the Argos river.

Table 1. Physical and chemical parameters of Argos riverin the sampling area (from Vidal-Abarca, 1985).

	Mean values (Vidal-Abarca, 1985)		**Mean values** (Vidal-Abarca, 1985)
pH	8.6	Magnesium (mg/l)	70.3
Salinity (g/l)	0.52	Suspended Solids(mg/l)	46.5
Conductivity (µS/cm)	1203	Nitrates (µg/l)	50.7
Alkalinity (meq/l)	6.9	Nitrites (µg/l)	1.4
Chloride (mg/l)	100.1	Amonium (µg/l)	4.7
O_2 (mg/l)	11.1	Phosphates (µg/l)	2.2
Hardness (°F)	41.6	Silicates (µg/l)	161.8
Calcium (mg/l)	50.6	Chl-a (mg/l)	7.5

Sampling procedure

Working groups and site replication

The main goal of the study was to harmonize and homogenize the field methodology, especially the sampling and sorting of macroinvertebrates, between researchers of six different centers. All of them have large experience on macroinvertebrate studies. As the researchers of each center have differences in sampling and sorting, and some of them were not used to apply the QBR, we design the field experiment dividing the researchers in working teams. To avoid the individual effect the exercise was designed as follows:

1. The researchers from the six centers were divided into 4 teams. Each one had to sample, sort and count the macroinvertebrates from a site in the river Argos. Teams were composed by 4-5 people.
2. At least one member of each center was present in each group.
3. The sampling was made in four different sites of Argos stream 200 m away from each other. Care was taken in selecting the sites to avoid the differences of fauna due to different substrata composition.
4. The following protocol for sampling, determining the physico-chemical parameters, assessing the riparian vegetation and sorting the samples was establish previous to be applied in the exercise.

Macroinvertebrates

In each stream reach, two samples were collected from the riffles (R) and pools (L) habitats, using the kicking method. All the macroinvertebrates retained by a net of 250 μm mesh size were collected.

Two protocols to be compared were established, based on the one designed by Prat *et al.* (2000):

PROTOCOL 1: The samples were processed and identified in the field, except the most difficult taxa that were kept in alcohol 70% to be identified in the lab. In the field, the contents of the nets were put in plastic trays and the different taxa found were recorded and quantified in four ranks: 1 (1-3 indv.), 2 (4-10 indv.), 3 (10-100 indv.) or 4 (>100 indv.). This procedure would stop when after successive sorting no more new taxa appeared (Alba-Tercedor, 1996; Alba-Tercedor & Pujante, 2000).

PROTOCOL 2: The samples collected with the Protocol 1 were kept in alcohol 70% and were sorted and identified in the lab using a stereoscope. All the taxa that were seen in the field but not collected or remained in the sample were also recorded (especially Hemiptera and Coleoptera). The abundance using the same ranks as the Protocol 1 was recorded for all sample.

Each team applied both protocols in its sampling site. For the Protocol 2, once in the lab, the largest animals were picked up and identified first, and the rest were sorted using a stereoscope, with successive fractions of 50 individuals for riffles and pools samples separately. The total number of taxa from each fraction and habitat (riffles or pools) and the number of individuals per taxa were obtained.

Finally, the IBMWP, FBILL and IASPT were calculated for each team and protocol and the data was analyzed using hierarchical cluster methods and ANOVAs, after checking for normality. The statistical software used was Biodiversity-Pro (McAleece *et al.*, 1997) and Statistica (StatSoft, 1999). The different taxonomic experts in the project identified the individuals collected. The list of all taxa recorded is shown in Annex 1.

Riparian Vegetation

All the researchers applied the riparian vegetation index QBR, designed for Mediterranean streams with a previous training of its use made by the Barcelona research team which has designed the index (Munné *et al.*, 1998). This index has been successfully applied in several streams in Catalonia (Prat *et al.*1997, Prat *et al.* 1999) and in the Segura river basin (Suárez & Vidal-Abarca, 2000).

RESULTS

Macroinvertebrates: selection of a biological index

For each protocol and team the IBMWP (for riffles and pools) and FBILL (only riffles) were calculated. The data, presented in Figure 2, indicates that there are no differences in water quality for both indices using both protocols. It can be seen that all the teams have arose the "Very good biological quality" for the FBILL and IBMWP indices.

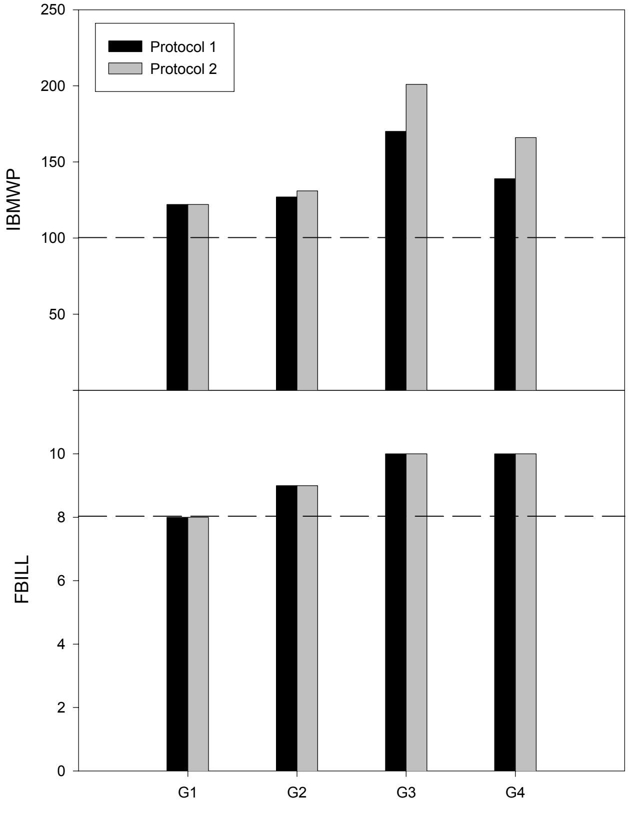


Figure 2. Values of IBMWP and FBILL for all sampling groups and both protocols. The IBMWP has been calculated using the community in the integrated sample (R+L) and the FBILL only in the lotic habitat (R). The discontinuous lines show the values of each biotic index and it can be considered a water quality of "Very good" (>100 in the IBMWP and between 8-10 in the FBILL) (G1, G2, G3 and G4=Groups 1, 2, 3 and 4).

Macroinvertebrates: effect of the sampling protocol

An analysis of the variance was performed to compare the number of families and the values of the IBMWP and IASPT, for both protocol and habitats, using each sampling team as replicates (n=4). According to the results, there are not significant differences between Protocol 1 and 2 in the IBMWP and IASPT indices (p=0.4884 and p=0.5924) (see Figure 3). Either, the total number of families found did not show differences between protocols (p=0.4832) or habitats (p(pools)=0.8351 and p(riffles)=0.7608).

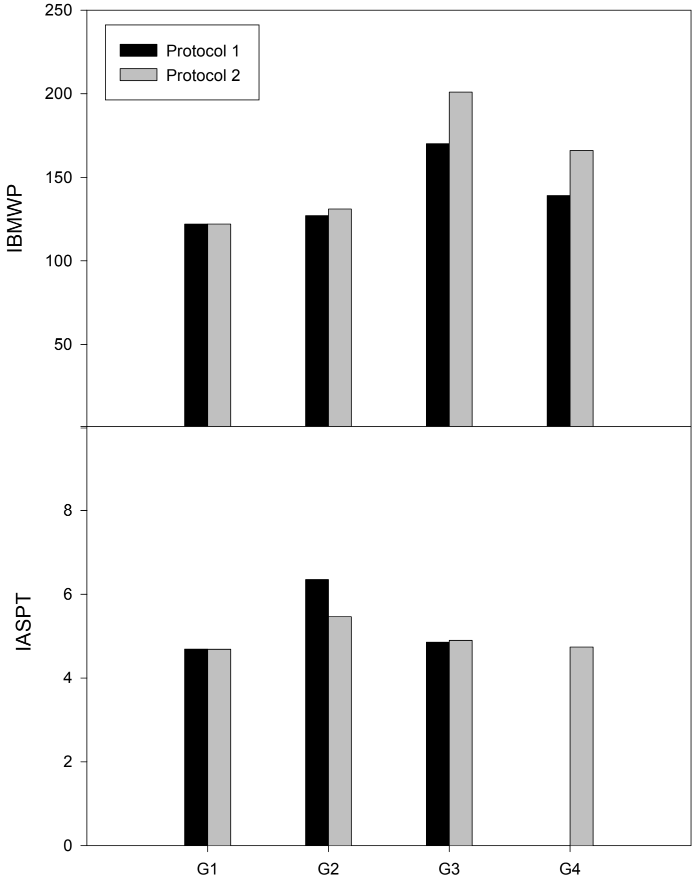


Figure 3. IBMWP and IASPT values following Protocols 1 and 2.

Although no significant differences were found between the number of families between both protocols, using the Protocol 2 a higher number of taxa was found in all the teams (Table 2), most of them small Diptera or Ostracoda, which where difficult to identify and to recognize in the field. The sampling team 2 was the one that observed a higher similarity between the numbers of taxa in both protocols.

Table 2. Families non-registered in field and found in the laboratory using Protocol 2, and their IBMWP values.

	Group	SBMWP score
Oligochaeta	G3	1
Ostracoda	G3	3
Lymnaeidae	G3	3
Caenidae	G1 and G4	4
Hydroptilidae	G3	6
Psychomyiidae	G3	8
Helodidae	G4	3
Sericostomatidae	G3	10
Elmidae	G3	5
Simuliidae	G4	5
Ephydridae	G4	2
Psychodidae	G4	4
Stratiomyidae	G2	4
Limoniidae	G3	4
Ceratopogonidae	G3	4

Macroinvertebrates: effect of the sampling team

Using presence/absence data of taxa found in the field and laboratory a cluster to check for similarities between sampling teams was performed. It was used the Jaccard index excluding the double absences (Figure 4). The major similarity between teams was found between groups 1 and 3 (50%), whereas team 2 was the most different (39% of similarity). However, the value of the IBMWP index in the field and lab of this team is close to those found by the other teams (Figure 3). The community found in team 2 although is poorer, has higher family scores, fact that could be related with a relative dominance of the riffle habitat in the reach sampled.

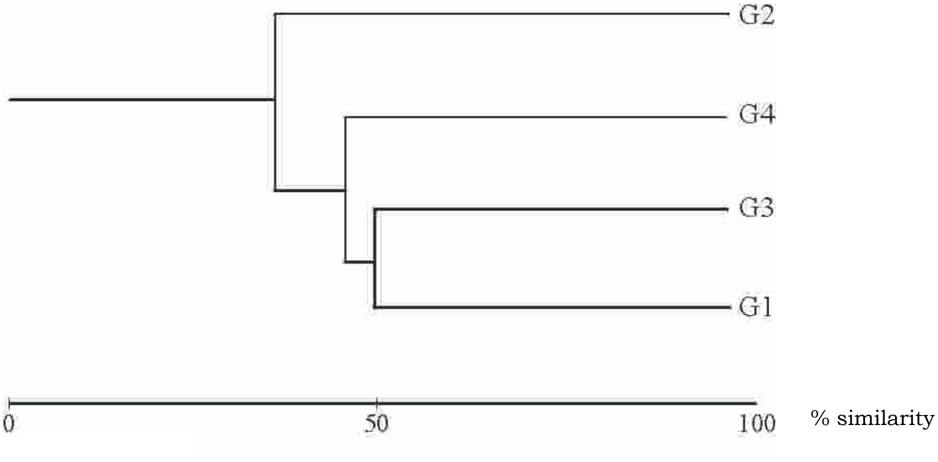


Figure 4. Dendrogram of the macroinvertebrate taxonomic composition found by eac
Jaccard's method.

Macroinvertebrates: effect of the counted individuals

In Figure 5, number of taxa, values of IBMWP and IASPT indices calculated and accumulated for successive teams of 100 individuals in both habitats is plotted (50 from riffles and 50 from pools). There is an important increase in the number of families and the values of the IBMWP from 100 to 200 individuals counted, following a relative stabilization. For the IASPT, the value obtained for each team after a count of 100 individuals does not change much with an increase of the sorting effort. That would strengthen the use of this index, respect to the others, because of its conservative property. The analysis of the variance performed to test the differences between teams for all the variables indicated the presence of significant differences between teams (p=0.000 for the number of families; p=0.000 for the IBMWP and p=0.008 for the IASPT). According to that, the team 3 has a highest number of families and so a higher IBWMP value; however, the IASPT value is intermediate, indicating that the increase of families has been done with the addition of taxa in both habitats (riffles and pools), which should be related to the higher sampling effort in the stream reach for this team than the others. In the team 2, although there is a lower number of families and a lower IBWMP, the IASPT is higher than in the other teams, which is related with a dominant riffle habitat in the reach and higher individual scores of the macroinvertebrate families found.

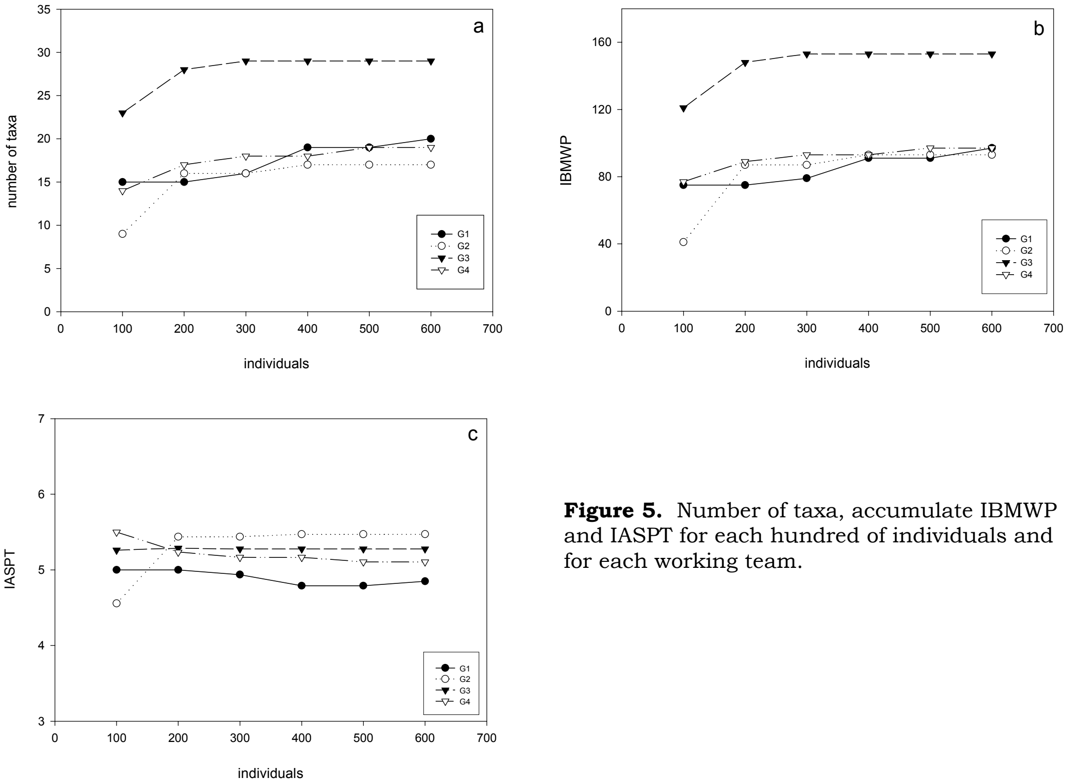


Figure 5. Number of taxa, accumulate IBMWP and IASPT for each hundred of individuals and for each working team.

The average values and the standard deviation of the number of taxa, IBMWP and IASPT indices for all teams and habitats are presented in Figure 6. It can be observed a sharp increase of the average values of each variable between the 100 and 200 individuals, although standard deviations are quite high. No significant differences were found in any case between the fractions of number of individuals counted (p=0.6912 for the number of families; p=0.7293 for the IBMWP and p=0.9788 for the IASPT). Consequently, a count of 100 individuals would be enough to get an optimum number of individuals, a IBMWP and IASPT indexes, respectively, although the high standard deviation present between groups.

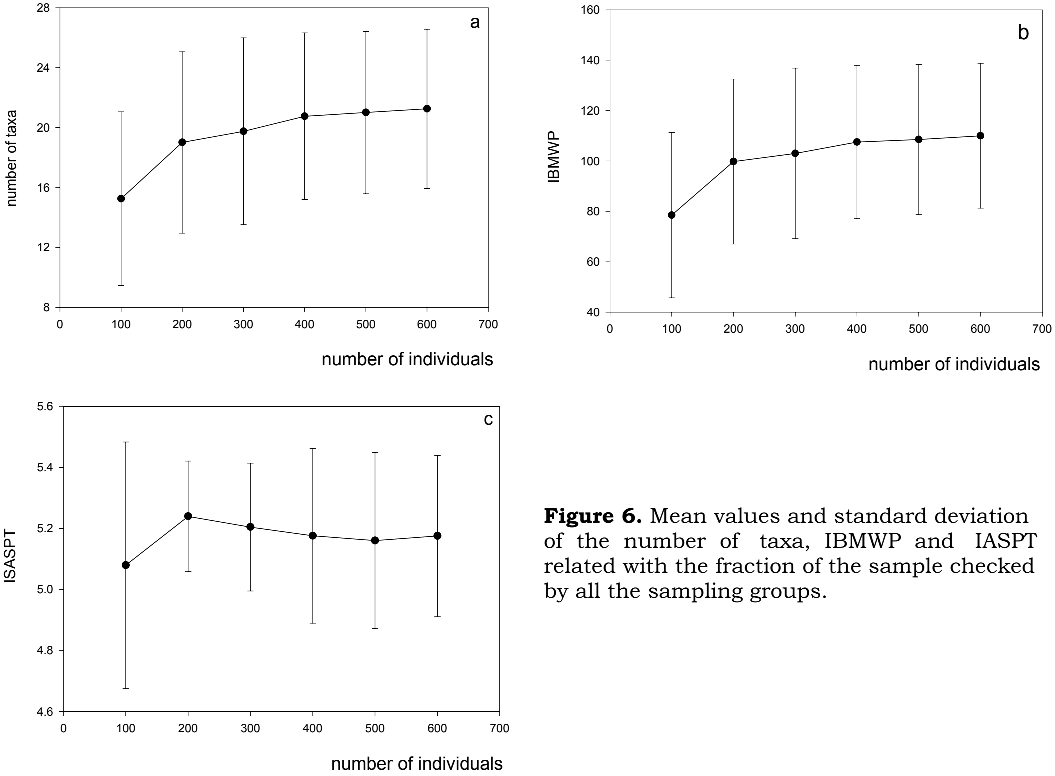


Figure 6. Mean values and standard deviation of the number of taxa, IBMWP and IASPT related with the fraction of the sample checked by all the sampling groups.

In Figure 7 differences between both habitats are shown. As in the other cases, it can be observed an asymptotic increasing of the number of taxa for each fraction of counted individuals and for both habitats. The analysis of variance performed to compare both habitats indicated significant differences between pools and riffles ($p<0.005$), with a higher diversity in the former. Moreover, with more individuals there is a tendency of a faster increase, in the taxa found in pools than in riffles. In Table 3, taxa exclusive for each habitat are presented. As can be expected, reophilic families as Simuliidae, Helodidae, Psychomyiidae, are only present in the lotic habitat, while Heteroptera, Odonata and Coleoptera are between the ones only found in the lentic samples.

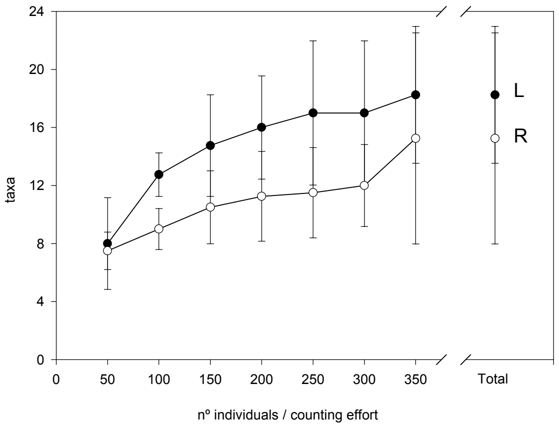


Figure 7. Number of taxa found related with the fraction of the sample checked by all the sampling groups, according to the lotic (R) or lentic (L) habitat.

Table 3. Exclusive taxa from lotic and lentic habitat.

Exclusive R	**Exclusive L**
Hydracarina	Coenagrionidae
Perlidae	Corduliidae
Aeshnidae	Cordulegasteridae
Helodidae	Dryopidae
Psychomyiidae	Haliplidae
Psychodidae	Hydraenidae
Simuliidae	Hydrophilidae
Stratiomyidae	Naucoridae
Tabanidae	Nepidae
	Notonectidae
	Polycentropodidae
	Ephydridae
	Glossiphoniidae

Riparian vegetation: effects of the sampling team

The analysis of variance performed to test differences in the QBR index between teams were significant ($p<0.001$). That could indicate two things: first, that the riparian vegetation is not uniform along the river, and therefore differences in QBR value are due to vegetation cover in the sampling reach. Another possibility is that index value disparities between reaches are due to insufficient training of the observers in the use of the index or linked to some subjectivity implicit in the index design allowing an observer effect (Munné *et al.*, in press). Although there are some differences in the values between the observers in the same team, the changes in the quality ranks are at most of only one level (Table 4).

Table 4. QBR values by teams and observers.

Group	QBR value form each group member	Average
I	40 – 40 – 20 – 25 – 30	31
II	70 – 70 – 50 – 70 – 75	67
III	40 – 30 – 30 – 35 – 25	32
IV	40 – 45 – 55 – 60 – 55 – 50	50

DISCUSSION

The Rapid Bioassessment Protocols have been proved to be useful in wide regions (Resh & Jackson, 1993; Resh *et al.*, 1995). Several authors have studied the performance of RBPs when reducing the number of samples, the sampled area, the effort in the counting or the taxonomic resolution, and the implementation of the sorting in the field, (Resh & Unzicker, 1975; Stribling *et al.*, 1993; Marchant *et al.*, 1995; Resh *et al.*, 1995; Plafkin *et al.*, 1989; Barbour & Gerritsen, 1996; Barbour *et al.*, 1999; Smith *et al.*, 1999). The GUADALMED1 Project covers a large area that includes most of the watersheds draining into the Mediterranean Sea from the Iberian Peninsula (from the Besòs basin in Catalonia to the Guadalfeo basin in Granada), that is of about one thousand kilometers straight distance and an altitudinal ranges from the sea level to 4000 m in Sierra Nevada. In this case, a RBP must be adequate for the assessment of water quality in Mediterranean streams in Spain following the implementation of the WFD with care.

When a sampling methodology has to be implemented in a new area, firstly several protocols should be tested, and the most useful has to be selected (Rosenberg & Resh, 1993; Resh *et al.*, 1995; Hill *et al.*, 2000; Wrigth *et al.*, 2000). In the researched area, many previous studies have been done on macroinvertebrates and some detailed protocols already exist applicable to some catchments (Prat *et al.*, 2000). In the present study, two main sampling protocols currently used in Mediterranean rivers have been tested, one exclusively based in data got from the field and the other combining field and laboratory information. In both, a semi-quantitative sampling method has been applied using the kicking technique. In the literature there is a large number of methods to collect macroinvertebrates according to the type of river and the objectives of the study (see Rosenberg, 1978; Elliot & Tullett, 1978, 1983). The kicking method is an easy one and has been recommended for biomonitoring surveys obtaining satisfactory results (Storey *et al.*, 1991; Metzeling & Miller, 2001). Moreover, an advantage of the non quantitative methods is that they can be used in substrates where the quantitative techniques are not applicable (Chessman & Robinson, 1987). The kind of data to be used (qualitative or quantitative) it is irrelevant to show community patterns, although at small scale or depending on the objectives to achieve, quantitative methods are need (Marchant, 1990).

Several authors suggest that the results obtained from combining samples from several habitats, give redundant information and therefore, one habitat could be enough to check for disturbance effects (Stribling *et al.*, 1993; Plafkin *et al.*, 1989). In mediterranean ecosystems, habitat availability may change naturally along the year, especially at the beginning of the drought period firstly with the lost of riffles and finally with the lost of pools (Gasith & Resh, 1999). As a consequence, protocols to be applied along year should be designed including both habitats. Thus, in these areas, as it has been suggested in other regions an integrated sample including lotic and lentic habitats could provide a better information about the river communities (Kerans *et al.*, 1992; Cuffney *et al.*, 1993), although it requires a greater sampling effort compared with the single-habitat methods.

Both indexes, IBMWP (Alba-Tercedor & Sánchez-Ortega, 1988) and FBILL (Prat *et al.*, 1999) have been shown to be properly applicable for assessing water quality in Mediterranean rivers. Moreover, several authors (Rico *et al.*, 1992; Prat *et al.*, 1997) showed high correlations between the FBILL or similar indices based in Trend index (Woodiwiss, 1964) and the IBMWP, indicating that both indices are useful for monitoring Iberian rivers. Because the importance of the lentic habitat in some mediterranean streams (mainly in summer) we discarded to apply FBILL index because it was designed to be applied only in runs and riffles and, therefore large part of the community may be lost using it. On the other hand, the IBMWP considers the sampling of both riffles and pools habitats and that is why it has been selected in the GUADALMED Project.

To assess the habitat diversity, Hannaford *et al.* (1997) compared the ability of students with and without training. The results were that the team with more experience had more precise results, far away from the other. In the same way, for macroinvertebrate identification, if the results got in the field have to be compared with the laboratory ones, the experience and traineeship are important. Smith *et al.* (1999) found that qualified researchers identified in the field 76% of the families present in a sampling site, and 90% in the laboratory. Thus, this would imply that the use of sampling Protocol 1, although it is faster and effective, requires a previous effort of trainership, especially if the Protocol must be applied by the government monitoring program technicians (which may have low biology and ecology skills). In our study, where in each working team there were members of different centers with a similar experience identifying macroinvertebrates in the field, the differences between communities should be due to changes in the habitat sampled and not to the lack of experience. In fact, our results indicate that when differences were present, field values had a higher IBMWP and a lower IASPT what could be related to a major presence of the lentic habitat, or high IASPT with intermediate IBMWP, related to a dominance of riffles. However, despite these differences, there was a high similarity in the quality rank of the IBMWP produced for each team.

Usually the number of taxa found in a sample increase asymptotically, when the effort of sorting and counting increases (Courtemanch, 1996; Vinson & Hawkins, 1996). That fact has produced strong arguments against the fixed counting method to assess the sample diversity (Cuffney *et al.*, 1993; Countermanch, 1996; Vinson & Hawking, 1996), although other studies show its usefulness in biomonitoring (Plafkin *et al.*, 1989; Barbour & Gerritsen, 1996; Tiller & Metzeling, 1998; Barbour *et al.*, 1999; Metzeling & Miller, 2001). According to our results, a fraction of 100 individuals would be enough to get an optimal number of families, and IBMWP and IASPT rank quality, after removing the largest organisms. However (Figure 5), both the number of taxa and IBMWP increases between 100 and 200 individuals in all the teams, although it is not significant because the high standard deviation. We consider that to get a safer IBMWP value and a more complete list of taxa, 200 individuals are required for routine monitoring in Mediterranean streams. Even though the value of IBMWP would increase using more than 200 individuals, the quality rank would remain the same (Alba-Tercedor & Sánchez-Ortega, 1988), indicating that the 200 individuals are enough to get a significant and representative quality rank even at lower standard deviation values. On the other hand, the IASPT seems to be stable even from 100 individuals (Figure 5), as it is a more conservative metric.

When both sampling protocols were compared, there were not significant differences between them in the number of families, and the IBMWP and IASPT indexes. Thus, the selection of one or the other does not affect the results in terms of water quality. However, in reference conditions the community is always more diverse (Reynoldson *et al.*, 1997) and the use of the Protocol 1 would imply a loss of information because the rare species or the smallest ones would not be detected. Therefore, because the data of references sites may be used not only for the biological quality classification (but also for other purposes, as to design of a RIVPACS-type assessment method) for the Guadalmed project it was agreed to use the Protocol 2.

In Marchant *et al.* (1995) and Marchant (1999) it has been suggested that the exclusion of the rare taxa does not imply a loss of ecological information. However, other studies (Cao *et al.*, 2001) demonstrate the importance of the rare species to get a good assessment of the water quality (Cao & Williams, 1999). In our study, although there are not differences between the IBMWP and IASPT determined by all the sampling teams (but note the high standard deviation), when the data for each team is analyzed separately the number of individuals required to stabilize the IBMWP and the IASPT are 200 and 100, respectively. This difference is due to the presence of rare taxa that let to a IBMWP increase, although the IASPT would remain stable. The rare taxa (with low abundance and frequency, and usually very small) found between 100 (optimum for IASPT) and 200 (optimum for IBMWP) individuals are important because they imply a significant increase of the IBMWP. The rare species would be the key species to assess the effects of the disturbances at a specific level, because usually they present narrow ecological niches (Cao & Williams, 1999). For instance, the Beraeidae family (low abundance and frequency) has a score of 10 in the IBMWP and its presence is limited to the small streams with mosses, gravel or sand. Consequently, after counting 200 individuals, as the number of taxa increase slightly without increasing IBMWP or IASPT rank, we suggest checking the rest of sample only for new and rare taxa that might provide extra information useful for specific studies.

Barbour & Gerritsen (1996) showed that counting between 100 and 300 individuals is enough to discriminate significantly different ecological patterns. However, the exact number required can vary between areas (Barbour & Gerritsen, 1996) and sites (Vinson & Hawkins, 1996). For instance, Carter & Resh (2001) presented how in the different states of North America the number of individuals counted differs from 100 to 500. According to our invertebrate exercise, made in a reference site, 200 individuals (after removing large animals) is a good number to assess biological quality in Mediterranean streams which is in the range applied in other countries (Carter & Resh, 2001).

The more appropriate taxonomical level to the assessment of the water quality has been highly discussed (Resh & Unzicker, 1975; Cranston, 1990; Marchant *et al.*, 1995; Bowman & Bailey, 1997). Using a lower taxonomical resolution implies a better precision and information (Furse *et al.*, 1984; Resh *et al.*, 1995), although the number of studies and biotic indices that use the family to assess water quality are large because of its simplicity and cost-efectiveness (Armitage *et al.*, 1987; Alba-Tercedor & Sánchez-Ortega, 1988; Corkum, 1989; Prat *et al.*, 1999, Hewlett, 2000). However, Stubauer & Moog (2000) point out the use of biological indices at family level could imply a loss of information about the environmental effect of the disturbance. Several studies shown that using higher taxonomical levels as families, the distribution patterns of the communities are similar than using the species level (Furse *et al.*, 1984; Ferrano & Cole, 1992; Rutt *et al.*, 1993; Marchant *et al.*, 1995; Zamora-Muñoz & Alba-Tercedor, 1996; Bowman & Bailey, 1997; Nielsen *et al.*, 1998). The IBMWP index, used in the GUADALMED methodology, uses the family level, and numerous studies in the Iberian Peninsula indicate its utility to detect disturbances (Zamora-Muñoz *et al.*, 1995; Alba-Tercedor, 1996; Zamora-Muñoz & Alba-Tercedor, 1996; García-Criado *et al.*, 1999; Alba-Tercedor & Pujante, 2000). On the other hand, Bowman & Bailey (1997) comparing similarity matrixes using the genus and the family level, found that the correlation between both levels in the disturbed sites are higher than in the reference ones. Bonada *et al.*, (2001) using the caddisfly community of the GUADALMED Project identified at the species or genus level, found that the general patterns are similar with those shown by the family level.

The QBR results indicate that there are differences between the values found in close sampling sites, which shows the dependency of the index from the local conditions as was pointed out in Munné *et al.* (1998). This peculiarity of the index is very important in the reference sites, where according to the WFD, these sites should have a very good ecological status, including riparian vegetation. Thus, the QBR method is a useful RBP to evaluate the status of the riparian vegetation. Although the index may be subject to some over or under evaluation when it is applied by several observers, values of quality do not change very much and the results improve with training (Munne *et al.*, in press). The method has been used by all the GUADALMED teams and results are published elsewhere (Suarez *et al.*, in press).

In summary, according to our exercise, to obtain the best results in the assessment of ecological status in the Mediterranean area, the protocol to be used will be different if the site is a reference station or not. In a reference site and to evaluate its biological quality, the Protocol 2 should be used counting and identifying until 200 individuals in the lab to avoid differences between basins and habitats, after sorting the biggest individuals (Cuffney *et al.*, 1993; Vinson & Hawkins, 1996). The use of Protocol 2 allow us to keep the samples to be analyzed until lowest taxonomic resolution, and made possible studies to look for patterns in the distribution of some taxa in the Mediterranean area (Bonada *et al.*, 2001). On the other hand, in the no-reference sites, the use of the Protocol 1 will be enough to provide data for biological index determination because the community is poorer, abundant and easier to identify (Countermanch, 1996). In both cases, combined samples from both habitats (riffles and pools) will be required. The use of Protocol 1 may simplify the routine analysis performed by water authorities and allows to improve the effectiveness per sampling site and even to increase the number of sites to be monitored. However, we understand that the use of Protocol 1 it should be only applied when the objective of the study is to assess biological quality, whereas in other cases (e.g., when studies about biogepographical distribution patterns of several taxa) Protocol 2 is needed to obtain the maximum information without biasing the results.

The intercalibration and selection of a sampling protocol to assess streams and rivers ecological status is an important step to take into account before starting any biomonitoring program in a wide area, because not all the methods are equally applicable (Rosenberg & Resh, 1993; Resh *et al.*, 1995; Hill *et al.*, 2000; Wrigth *et al.*, 2000). Moreover, the objectives of those methods could be different from ours (Barbour *et al.*, 1999). The WFD requires assessing the ecological status using biological criteria, and so protocols based in this idea have to be implemented in Europe. These protocols must be easy to apply and cost-effective, as they will be used by the administration although a minimum of training is required (Hannaford *et al.*, 1997) to get optimal results.

GUADALMED RBP PROTOCOL

Protocol 1. Non-reference sites
Only for biological assessment studies

- Sampling all the available habitats in a 100 m reach.
- Kicking method with a mesh size of 250 µm, removing all the substrate upstream of the net.
- For the riffle habitats, locate the net in front of the rock, remove the substrate and clean well the rocks.
- For the pool habitats, sweep the bank vegetation, and remove the gravel substrate of the pools.
- Before the net is clogging, put the collected material in plastic white trays.
- Check often the different taxa found in the tray and identify. Record them in the field sheet with a abundance rank: 1 (1-3 indv.), 2 (4-10 indv.), 3 (10-100 indv.) or 4 (>100 indv.).
- Keep in vials with alcohol 70% the taxa difficult to identify on the field.
- Repeat the sampling process until no more new taxa is observed.
- Identify in the lab the taxa collected.
- Calculate the biotic index IBMWP and IASPT using all taxa found in the field or in the lab for both habitats.

Protocol 2. Reference sites
Depending on the objectives, non-reference sites should be also sampled using Protocol 2

- Sampling all the available habitats in a 100 m reach.
- Kicking method with a mesh size of 250 µm, removing all the substrate upstream of the net.
- For the riffle habitats, locate the net in front of the rock, remove the substrate and clean well the rocks.
- For the pool habitats, sweep the bank vegetation, and remove the gravel substrate of the pools.
- Put all the contents of the net in a plastic white tray and take a quick look to identify major taxa. Put the material in a labeled plastic jar with alcohol 70%, or formol 4% for the lentic and lotic habitats, separately.
- Repeat the sampling process to check only for non-collected taxa.
- Bring the samples to the lab. Sort the biggest invertebrates with forceps, identify them.
- Using a stereoscope, sort 200 individuals of the sample, identify and record the abundance of all sample: 1 (1-3 indv.), 2 (4-10 indv.), 3 (10-100 indv.) or 4 (>100 indv.).
- Check the rest of sample looking for new taxa not found and record their abundance.
- Calculate the biotic index IBMWP and IASPT using all taxa found in the field and the lab for both habitats.

For all sites

- Sampling 4 times per year: spring, summer, autumn and winter.
- Measure temperature, pH, discharge, conductivity and oxygen with field devices.
- Collect a water sample to analyze the chemical parameters established in the WFD.
- Measure the QBR index using the field sheet.

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Annex 1. List of taxa found in the sampling site.

OLIGOCHAETA	
ACHAETA	Erpobdellidae
	Glossiphoniidae
TURBELLARIA	Planariidae
CRUSTACEA	*Echinogammarus* sp.
MOLLUSCA	*Lymnaea truncatula*
	Lymnaea peregra
	Physella acuta
	Hydrobiidae
	Potamopyrgus jenkinsi
EPHEMEROPTERA	*Alainites muticus*
	Baetis pavidus
	Baetis rhodani
	Cloeon dipterum
	Procloeon bifidum
	Caenis luctuosa
	Ecdyonurus gr. *ruffi-wautieri*
PLECOPTERA	Nemouridae
	Perlidae
COLEOPTERA	*Nebrioporus clarki*
	Deronectes hispanicus
	Bidessus minutissimus
	Graptodytes fractus
	Agabus gr. *brunneus*
	Agabus ddymus
	Agabus biguttatus
	Hidroporus discretus
	Lacophilus hyalinus
	Lacophilus minutus
	Haliplus lineatocollis
	Haliplus mucronatus
	Anacaena limbata
	Anacaena globulus
	Helochares lividus
	Laccobius gracilis
	Laccobius hispanicus
	Ochthebius quadrifoveolatus
	Ochthebius marinus
	Limnebius maurus
	Limnius volkmari
	Dryops gracilis
	Pomatinus substriatus
	Helophorus flavipes
	Elmis mauguetti
	Hydrocyphon sp.
	Elodes sp.
ODONATA	*Pyrrhosoma nymphula*
	Orthetrum coerulescens
	Orthetrum cf.
	Cordulegaster annulatus
	Onychogomphus forcipatus
	Onychogomphus uncatus
	Anax imperator
	Boyeria irene
HETEROPTERA	*Naucoris maculatus*
	Notonecta maculata
	Sigara nigronileata
	Nepa cinerea
	Microvelia pygmaea
	Hydrometra stagnorum
TRICHOPTERA	*Rhyacophila* gr. *munda*
	Agapetus sp.
	Hydropsyche gr.
	Stenophylax sp.
	Plectrocnemia sp.
	Tinodes waeneri
	Sericostomatidae
	Mesophylax aspersus
	Hydroptila vectis
DIPTERA	Tanypodinae
	Tanytarsini
	Orthocladiinae
	Corynoneurinae
	Quironomini
	Athericidae
	Limoniidae
	Dixidae
	Psychodidae
	Tipulidae
	Ceratopogonidae
	Tabanidae
	Simuliidae
	Stratiomyidae
	Ephydridae

Chapter 2

A COMPARISON OF SAMPLING METHODOLOGIES TO ASSESS BIOLOGICAL QUALITY IN TWO MEDITERRANEAN AREAS[1]

INTRODUCTION

Rapid Bioassessment Protocols (RBPs) have been widely used in different countries to assess biological river quality (Wright *et al.*, 1984; Plafkin *et al.*, 1989; Davies, 1994; Chessman, 1995; Growns *et al.*, 1995; Tiller & Metzeling, 1998; Chutter, 1998; Barbour *et al.*, 1999). All these methodologies intend to be efficient, effective, low in cost and easy to use (Resh & Jackson, 1993; Lenat & Barbour, 1994; Resh *et al.*, 1995), but significant differences exist between sampling procedures and metrics used. Numerous metrics are used to evaluate biological conditions (Kerans *et al.*, 1992; Lenat & Barbour, 1994; Resh, 1994; Resh *et al.*, 1995; Barbour *et al.*, 1996) but biotic indexes have been the most used around the world (e.g., Washington, 1984). Although several shortcomings in the use of indexes to assess water quality are found (Washington, 1984; Norris & Georges, 1993), they have been commonly used as metrics highly robust, sensitive, cost-effective and easy to apply and to interpret (Chessman *et al.*, 1997).

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[1] This Chapter will be submitted to an international journal under the same title and authored by the following researchers: Bonada, N.; Dallas, H.; Rieradevall, M.; Day, J. & Prat, N.

The organisms more used to assess biological quality are periphyton, macroinvertebrates and fish (Plafkin *et al.*, 1989; Barbour *et al.*, 1999). Traditionally, macroinvertebrates have been the most commonly used organisms (see Rosenberg & Resh, 1993; Chessman, 1995), and a large set of biotic indexes operates around the world (Davis, 1995). These indexes have different sampling methodologies in terms of gears and mesh size used, sampling habitats, sampling intensity and/or processing of samples, but in general, a qualitative or semi-quantitative sampling is performed in the sense of RBPs (Lenat & Barbour, 1994). Several authors have studied the effect of the sampling technique used and metrics to assess water quality, and differences among them but complementary results have been reported (Barton & Metcalfe-Smith, 1992; Kerans *et al.*, 1992). Sampling habitats also vary among sampling protocols, although in the RBPs where sampling effort is kept at the minimum possible level, a single sample from "most productive habitat" have been proposed as optimum (Plafkin *et al.*, 1989). However, because of human impact can be specific to an unknown particular habitat and/or sometimes the most productive habitat is not evident, other protocols emphasize samplings in all habitats (Kerans *et al.*, 1992; Stribling *et al.*, 1993; Resh *et al.*, 1995). The processing of samples also is important in RBPs, and a large variety of methods and controversies about the fraction of sample to be used are present (see Carter & Resh, 2001). Some methods are designed to be processed in the field, when usually macroinvertebrates are identified at family level (Prat *et al.*, 2000). Taxonomical level to be used in bioassessment also have been highly discussed (Resh & Unzicker, 1975; Cranston, 1990; Marchant *et al.*, 1995; Bowman & Bailey, 1997), and although a lower taxonomical resolution implies a better precision and information (Furse *et al.*, 1984; Resh *et al.*, 1995; Stubauer & Mogg, 2000), family level shows similar distribution patters of communities than genera or species (Furse *et al.*, 1984; Ferrano & Cole, 1992; Rutt *et al.*, 1993; Marchant *et al.*, 1995; Zamora-Muñoz & Alba-Tercedor, 1996; Bowman & Bailey, 1997; Nielsen *et al.*, 1998). Consequently, numerous biotic indexes use the family level because of its simplicity and cost-effectiveness (Armitage *et al.*, 1987; Hilsenhoff, 1988; Alba-Tercedor & Sánchez-Ortega, 1988; Corkum, 1989; Prat *et al.*, 1999, 2000, Hewlett, 2000). As a consequence of this high variability in sampling techniques and processes (Carter & Resh, 2001), methods can have different bias, and thereby comparisons between biotic indexes from different areas can be difficult (Erman, 1981; Kerans *et al.*, 1992; Diamond *et al.*, 1996).

Mediterranean climate is defined in terms of precipitation (di Castri, 1973) and temperature (Aschmann, 1973) with hot and dry summers and cool and wet winters. Consequently, mediterranean rivers are subjected to a natural flow disturbance that implies the presence of seasonal floods and droughts (Molina *et al.*, 1994; Gasith & Resh, 1999). Although a high similarity is noticed in the macroinvertebrate responses to habitat, temporality and pollution (Bonada *et al.*, Chapter 3), local factors related to the microclimate, geology or substrate are the responsible of several differences in communities found between mediterranean regions. As a consequence, a RBP methodology developed in one mediterranean region could not be applied successfully in another, and therefore comparative studies to examine the applicability of methodologies in other areas are required. In that sense, Diamond *et al.* (1996) recommend a comparison of methods in reference and test sites.

The aim of this study is to compare the applicability of two RBPs methodologies used to assess biological quality in two mediterranean areas: SASS5 in South Africa (South African Scoring System vs.5) and IBMWP (Iberian Biological Monitoring Working Party) according to Guadalmed protocol in Spain (Bonada *et al.*, Chapter 1; Jaimez-Cuéllar *et al.*, in press). Both methodologies are designed to be applied in the field, identifying macroinvertebrates at family level and the metrics used to calculate the biologic index are similar. However, although both are multihabitat approaches, the habitat to be sampled, the gears used and sampling and sorting procedures are different. SASS5 (Chutter, 1998) and IBMWP (Alba-Tercedor & Sánchez-Ortega, 1988; Alba-Tercedor, 1996) are analogous to the BMWP used in Great Britain (Armitage *et al.*, 1983), FBI in United States (Hilsenhoff, 1988) and SIGNAL in Australia (Chessman, 1995, Chessman *et al.*, 1997). Both indexes have been largely applied in their respective countries giving good results and being sensitive to water pollution (Camargo, 1993; Dallas, 1995, 1997; Zamora-Muñoz *et al.*, 1995; Alba-Tercedor, 1996; Zamora-Muñoz & Alba-Tercedor, 1996; García-Criado *et al.*, 1999; Prat *et al.*, 1999; Alba-Tercedor & Pujante, 2000).

METHODOLOGY

Sampling sites

Macroinvertebrates were sampled simultaneously in a number of sites in South Western Cape (South Africa) and Catalonia (Spain) by the two former authors of this Chapter (one from South Africa –H.D.– and another from Spain –N.B.–). Each one applied their own methodology in either Spanish and South African streams and the macroinvertebrates found were used to calculate biotic indexes from each region. Both have high skills and a long experience in macroinvertebrate sampling and field identification.

All samples were collected in spring season for an appropriate comparison: October of 2001 in South Africa, and April 2002 in Spain. In South Africa, 6 sampling sites from Eerste and

Palmiet basins were selected to perform the study (Figure 1a, Table 1). Langrivier (LA), Sosyskloof (SO) and Swartoskloof (SW) are tributaries from Eerste River, and are considered headwater streams. In Eerste River one site was located in the headwaters (EM), and the other downstream (EC) before the town of Stellenbosch. The site from Palmiet River is considered a foothill-lowland river site and it belongs to the Kogelberg Nature Reserve. All sites are located in the South African mediterranean area with vegetation dominated by mountain fynbos, with *Metrosideros angustifolia* or *Brabejum stellatifolium* in the riparian area and *Prionium serratum* in river banks, although in EC some introduced trees were found (*Acacia melonoxylon*, *Quercus robur*). Headwater sites and Palmiet have brown, acid and oligotrophic waters whereas EC have a slightly higher pH and conductivity, and significant agriculture runoff has been reported (Brown & Dallas, 1995). Thereby this site is considered as impaired in contrast to the others. Substrate is dominated by boulders, large stones and bedrock in the headwaters, and stones, pebbles and coarse sand downstream. Algae are scarce in such acidic conditions, but some macrophytes and mosses are abundant as instream vegetation in the lotic habitats of SW, EM and PA.

Table 1. Geographical, physical and chemical characteristics of the rivers sampled in South Africa and Spain.

		Category	Code	Altitude m.a.s.l.	Stream Ordre at 1:250000	Conductivity µS/cm	Temperature °C	pH	O_2 mg/l	O_2 %
	EERSTE BASIN									
SOUTH AFRICA	**Eerste mountain stream**	**Mountain stream**	**EM**	390	2	27.1	15.8	6.4	9.52	93.1
	Swartboskloof	**Mountain stream**	**SW**	390	1	25.2	15.7	5.9	7.5	75.5
	Sosyskloof	**Mountain stream**	**SO**	390	1	25.2	17.9	5	7	73
	Langrivier	**Mountain stream**	**LA**	390	1	25.9	17.4	5.8	8.45	84.6
	Eerste foothill	**Foothill**	**EC**	170	3	74.9	20	6.8	8.15	85.4
	PALMIET BASIN									
	Palmiet transitional	**Foothill-lowland**	**PA**	50	5	102.2	20.3	6.4	9.21	96.3
	BESÒS BASIN									
SPAIN	**Gallifa river**	**Mountain stream**	**B24**	560	1	695	11.3	8.4	10.07	96.4
	Ripoll river	**Foothill**	**B22**	340	2	654	16.1	8.6	8.85	92.6
	Tenes river	**Mountain stream**	**B28**	570	2	734	14.7	8.4	11.44	119
	Tenes river	**Foothill**	**B25**	250	2	778	14	8.4	10.41	102
	SIURANA-EBRE BASIN									
	Montsant river	**Foothill**	**MONT**	530	2	-	-	-	-	-

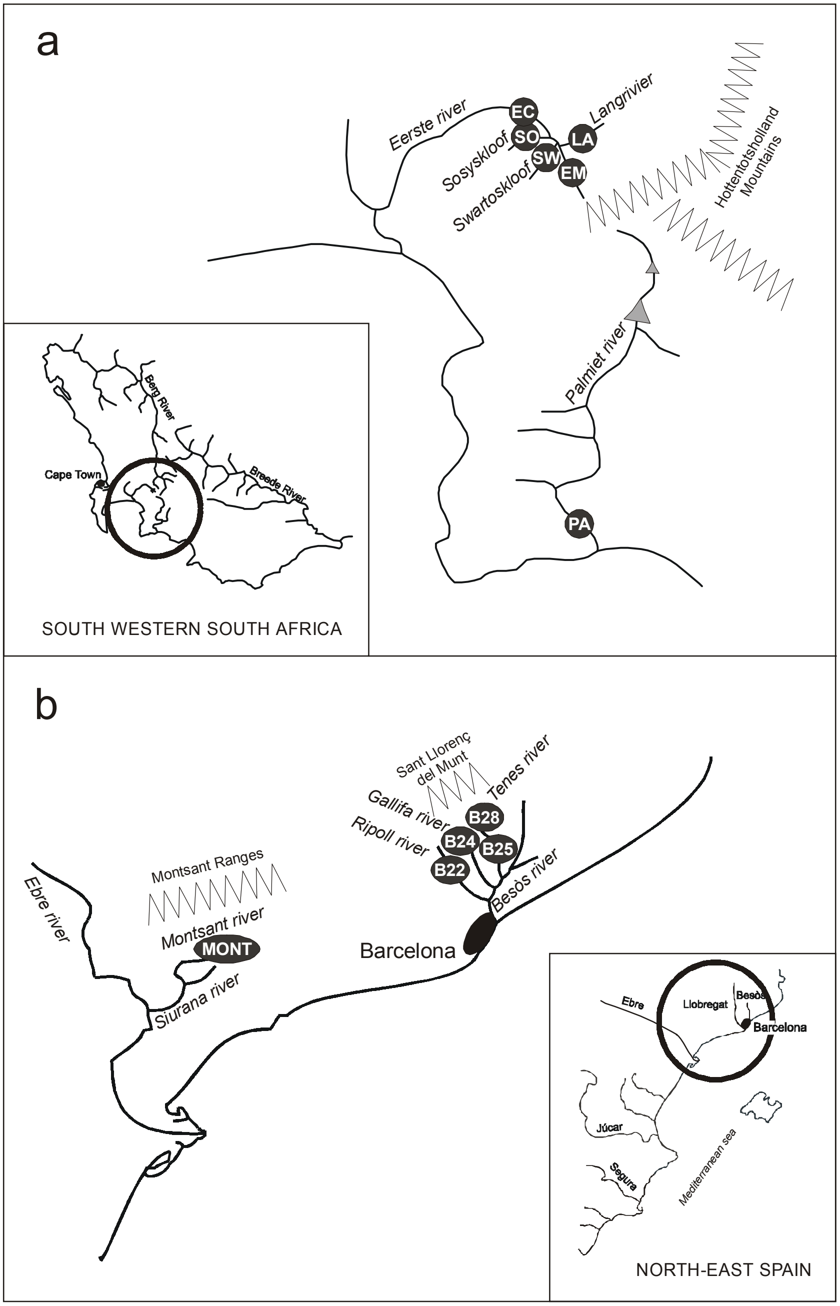

Figure 1. Sampling site location in South Africa (a) and Spain (b).

In Spain, 5 sites were sampled from Besòs and Siurana basins (Figure 1b, Table 1). Gallifa (B24), Tenes (B28, B25) and Ripoll (B22) are tributaries from Besòs River and have a calcareous and sedimentary geology. Most of the water comes from Sant Llorenç Natural Park, but only B24 and B28 could be considered as mountain streams. In these sites, the basin is forested with sclerophyllous mediterranean forest, and riparian vegetation with *Salix alba*, *Corylus avellana, Populus nigra* and *Populus alba* as dominant species. Downstream, in the foothill areas, the basin has a significant human alteration which affects water quality and riparian vegetation (e.g., presence of introduced species as *Platanus hispanica, Populus deltoides* and *Robinia pseudoacacia*) (Prat *et al.*, 1997, 1999). Montsant River is a tributary of Siurana River (tributary from Ebre River) that flows through the Montsant Natural Park with a predominant calcareous geology. MONT and B24 can be considered as pristine sites in contrast to B22, B25 and B28, influenced by human disturbances (Prat *et al.*, 1997, 1999). Instream vegetation is dominated by mosses, diatoms, zygnematales and *Cladophora* sp. Macrophytes as *Apium nodiflorum* or *Veronica* sp. are dominant in the river channel. Channel substrate is composed by bedrock, large stones and sand in headwaters and bedrock, pebbles and coarse sand in foothills.

Sampling methods

SASS5 methodology (Chutter, 1998)

A kick-net of 30x30 cm and 1 mm of mesh size is used in two groups of habitats: stones (S) and vegetation (V). Stone habitat includes stones-in-current (SIC) and stones-out-of-current (SOOC), and they are sampled in a different way. For SIC habitats a kick sampling is performed during 2 minutes if unattached stones are present or 5 minutes if not. For SOOC habitats 1 m^2 of the riverbed is sampled. Vegetation (V) includes marginal and instream vegetation, and they are sweeping with the net for 2 m. All collected material separated by habitat is poured into two different trays. Leaves, twigs and trash are removed from the tray to make easier to find the macroinvertebrates. Taxa is sorted and identified at family level except for Hydropsychidae and Baetidae for 15 minutes in the field or until no new taxa have been seen after 5 minutes of sorting. Organisms not collected but seen in the field (e.g., Heteroptera) are also included. The final SASS5 score is calculated using either stones or vegetation habitats. Number of taxa and ASPT value (i.e., SASS5/number of taxa) are also obtained. Abundances are estimated according to following ranks: 1=1, 2=2-10, 3=10-100 4=100-1000 5=>1000. In the text, SASS5 methodology will be referred as SV (stones-vegetation method).

IBMWP methodology (Alba-Tercedor & Sánchez-Ortega, 1988) according to Guadalmed Project (see Chapter 1)

In a 100 m reach, a kicking method is performed with a 250 μm mesh size net. Although all habitats must be sampled together, traditionally two groups of habitats have been identified and sampled separately, the riffles (R) and the lentic areas (L). For the lotic habitats, the net is located in front of the rock, removing the substrate and cleaning well several rocks, before the net is clogging. In lentic habitats, marginal vegetation, gravel and mud are swept. All material is put into white trays and leaves and sticks are removed. Organisms are sorted and identified in the field at family level until all collected material has been examined. The sampling procedure is repeated until no more new taxa are recorded. Organisms not collected but seen in the field (e.g., Heteroptera) are also included in the index calculation. The final IBMWP, IASPT and number of taxa are obtained using all taxa collected from both habitats. Abundances are estimated according to the following ranks: 1=1-3, 2=4-10; 3=11-100; 4=>100. Because the objective of the study was to compare both methods, and SASS5 is designed to be performed in the field, we use the Protocol 1 (see Chapter 1) for all samples. In the text, IBMWP methodology will be referred as RL (riffles-lentic method).

Table 2. Similarities and differences between SASS5 and IBMWP procedures, considering the items proposed by Resh *et al.* (1995).

Consideration	**SASS5**	**IBMWP**
1. Habitats to be examined	Stones (SIC and SOOC) and Vegetation (marginal and instream).	All habitats, separated in riffles (R) and lentic (L) areas.
2. Sampling area and intensity	Depending on the habitat.	100m reac h. Until no more new taxa are found.
3. Sampling devices	Kick -net.	Kick -net.
4. Mesh sizes	1000 ?m	250 ?m
5. Proportion examined	Time and taxa dependent.	All.
6. Taxonomic level	Family and species for Baetidae and Hydropsychidae.	Family
7. Measures used	Number of taxa, SASS5 score and ASPT score.	Number of taxa, IBMWP score and IASPT score.
8. Quality control and assurance	Samples from reference sites (H. Dallas, per. comm.).	Samples from reference sites (Bonada et al., in press).

Similarities and differences between sampling protocols are shown in Table 2. SASS5 procedure is focused in differences among physical substrates, whereas IBMWP use the flow as habitat differentiation.

Data analysis

To check for similarities and differences between communities and sites between both methods, a Non-metric Multidimensional Scaling (NMDS) was applied to the abundance's matrix. This ordination method preserves the distances between objects, plotting dissimilar objects far from the similar ones, (Legendre & Legendre, 1998). On the other hand, the NMDS method is not based on eigenvalues, and the final axes are arbitrary without enclosing the explained variability. Because of data is semiquantitative in ranks, Bray-Curtis coefficient was selected to calculate distances between variables and % of similarities between sites. PCORD program (McCune & Mefford, 1999) was used to carry out NMDS.

We next examined whether differences in macroinvertebrate community found using the Spanish and South African methods were significant or not. To perform that, a MRPP test (Multi-response Permutation Procedures) was used. This analysis is a non-parametric method that test multivariate differences among pre-defined groups (RL vs. SV —Riffles and Lentic versus Stones and Vegetation), providing the statistic A and a p-value obtained by permutation (999 runs) as result. Because its non-parametric condition this method is more appropriated than MANOVA in comparisons of data matrixes that involve species abundances including many zero values. To check for similarities and differences between biotic indexes and metrics, a non-parametric Kruskal-Wallis ANOVA by rank test was used, because of data were not normal using Shapiro-Wilk's test. The PCORD (McCune & Mefford, 1999) and STATISTICA (Stat Soft, 1999) programs were used to perform the analysis.

RESULTS

In total, 51 families were recorded in Spain and 44 in South Africa with both methodologies. The number of common taxa found by N.B. and H.D. using both methods was high, with 74.5% (38 families) of congruity in Spain and 78.3% (36 families) in South Africa (Table 3). Families found for one of the method but not the other were different in Spain and South Africa. In South Africa H.D. found 7 families not found by N.B. which collected 3 not found by H.D.; whereas in Spain, N.B. found 9 families not collected by H.D. which found 4 not found by N.B. (Table 3). In spite of these differences in methodologies, high Bray-Curtis similarities in community composition using both methods are found, with >68% in Spanish sampling and >75% in South African study.

Table 3. Macroinvertebrate families (in alphabetic order) found by each local and outsider researchers in both sampled mediterranean regions

	Only N.B. (local expert)	Only H.D.	Found by both N.B and H.D.				
SPAIN Sampling	Ancylidae	Cambaridae	Aeschnidae	Corixidae	Hydracarina	Naucoridae	Simuliidae
	Dixidae	Gammaridae	Asellidae	Culicidae	Hydraenidae	Nemouridae	Tipulidae
	Hydroptilidae	Helodidae	Baetidae	Dytiscidae	Hydrobiidae	Nepidae	
	Libellulidae	Veliidae	Bythinellidae	Elmidae	Hydrometridae	Oligochaeta	
	Lymnaeidae		Caenidae	Ephemerellidae	Hydrophilidae	Ostracoda	
	Planorbidae		Calopterygidae	Erpobdellidae	Hydropsychidae	Perlodidae	
	Polycentropodidae		Ceratopogonidae	Gerridae	Leptoceridae	Philopotamidae	
	Psychodidae		Chironomidae	Gomphidae	Leptophlebiidae	Physidae	
	Stratiomyidae		Coenagrionidae	Heptageniidae	Limnephilidae	Rhyacophilidae	

	Only H.D. (local expert)	Only N.B.	Found by both N.B and H.D.			
SOUTH AFRICAN Sampling	Aeschnidae	Gerridae	Baetidae	Dugesiidae	Hydraenidae	Philopotamidae
	Athericidae	Gomphidae	Barbarochthonida	Dytiscidae	Hydropsychidae	Pisuliidae
	Belastomatidae	Protoneuridae	Blephariceridae	Ecnomidae	Leptoceridae	Potamonautidae
	Heptageniidae		Caenidae	Elmidae	Leptophlebiidae	Simuliidae
	Hydroptilidae		Ceratopogonidae	Empididae	Libellulidae	Teloganodidae
	Naucoridae		Chironomidae	Glossosomatidae	Limnichidae	Tipulidae
	Platycnemididae		Coenagrionidae	Gyrinidae	Notonemourida	Veliidae
			Corydalidae	Helodidae	Oligochaeta	
			Dixidae	Hydracarina	Petrothrincidae	

The NMDS analysis (Figure 2) indicates that both methods discriminate mountain streams sites from foothills. Either, Spain and South Africa present a closer assemblage among methodologies than sites, especially in the foothills in Spain and headwaters in South Africa. Foothills sites present higher distances between methods, which would indicate that not coincident macroinvertebrate assemblages are produced depending on the methodology applied (Figure 2). In South Africa, Palmiet River site displays a unique community with a similarity of 75% between RL and SV methods, whereas headwater sites have the highest similarities between methods (over than 90%). This high similarity between methods is confirmed with the MRPP analysis indicating non-significant differences in the macroinvertebrate assemblages either in Spain (A=-0.021, p=0.6814) and South Africa (A=-0.0293 and p=0.792).

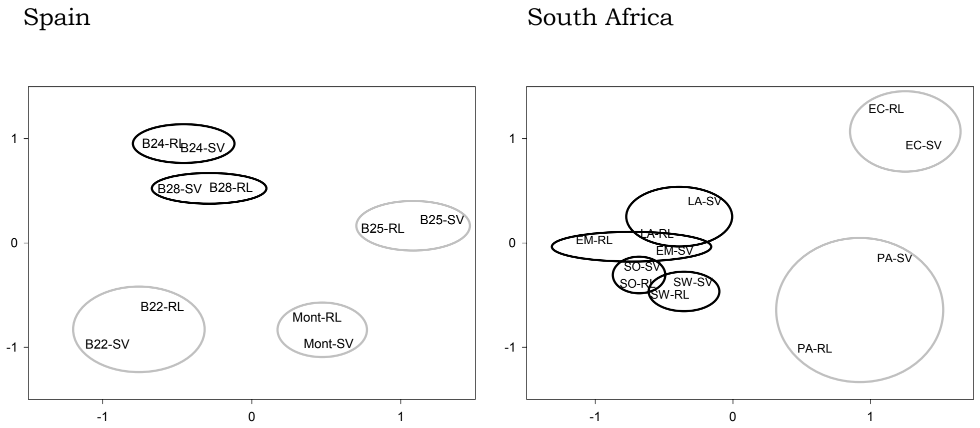

Figure 2. NMDS analysis in Spain and South Africa using SASS5 and IBMWP methods. Black circles indicate headwater sites, whereas grey ones are referred to foothills localities

Table 4. Results from the Kruskal-Wallis non-parametric tests comparing SASS5 and IBMWP methodologies in Spain and South Africa. ***p<0.01

		p-values		
		IBMWP	Taxa	IASPT
SPAIN	RL vs SV	0,5948	0,4172	0,7625
	R vs S	0,0578	0,1967	0,5271
	L vs V	0,5271	1	0,5271
	RS vs LV	0,0736	0,3711	0,3711

		p-values		
		SASS5	Taxa	ASPT
SOUTH AFRICA	RL vs SV	1	0,2207	0,2482
	R vs S	0,2482	0,079	0,2482
	L vs V	0,7401	0,621	0,3765
	RS vs LV	0.0064***	0.0001***	0,0589

Similarities between methods are also seen when values of the biological indexes and metrics are examined (Figure 3). There are not significant differences between RL and SV methods for the values of IBMWP (Spain) and SASS5 (South Africa) (Table 4). Furthermore, a high similarity is found in number of taxa or IASPT and ASPT scores, indicating that both methods provide equivalent results in both areas. The Spanish sampling sites present in average a lower IBMWP than the South African ones for both methods, but similar number of taxa, indicating that families with lower biotic scores are present providing a lower IASPT (Figure 3). Only one sample in Spain (MONT) presented a very high IBMWP score. In contrast, in South Africa only one site presented low biological quality (EC), as can be seen in Figure 3. When differences on RL and SV methodologies are analyzed by individual habitats, no difference are found between R and S or L and V (Table 4), but significant higher values in SASS5 and number of taxa is obtained comparing RS and LV in South Africa but not in Spain. A high biotic quality is observed in R and S habitats individually compared with L and V, indicating that R and S contributed more to the final score than L and V (Figure 3). In spite of these differences, ASPT remain constant among habitats. In Spain, where in average all sampling sites have a lower biological quality, these differences were not found, and a similar IBMWP, number of taxa and IASPT was recorded in all habitats for both methods. MONT site, displays a similar behavior than South African samples (except EC), with a lower IBMWP in L and V than R and S, but lower IASPT for all habitats. The site EC (the less clean site in South Africa) responds in the same way than most of Spanish sites, and no differences among habitats are observed (Figure 3).

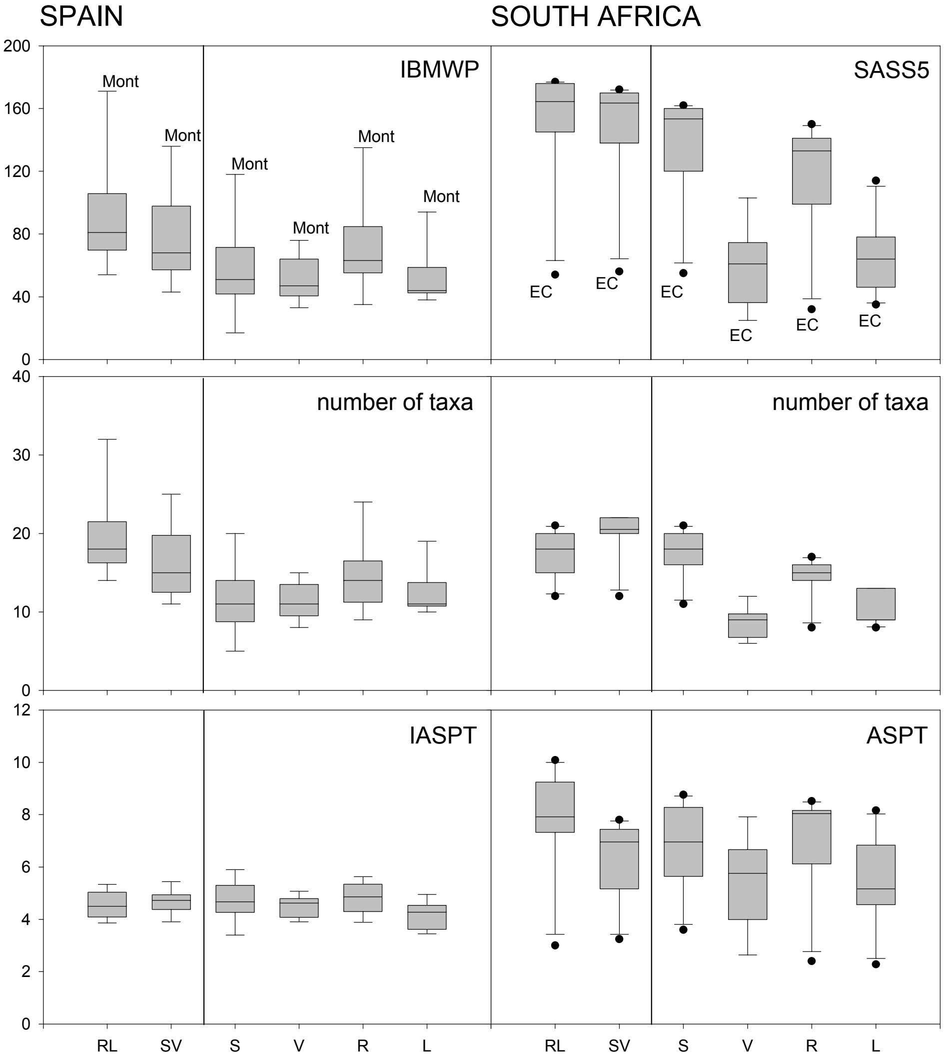

Figure 3. Box-Plot graphs from three tested metrics in Spain (IBMWP, taxa richness and IASPT) and South Africa (SASS5, taxa richness and ASPT) separated by methods and habitats. Mont (Montsant site in Spain) and EC (Eerste foothill site in South Africa) sites are indicated as extreme values in each region compared with the rest of localities. RL=riffles+lentic, SV=stones+vegetation, R=riffles, L=lentic, S=stones and V=vegetation.

DISCUSSION

There are a great variety of RBPs methods differing in sampling, subsampling, taxonomic resolution, metrics and index calculation, but all of them can yield comparable results depending of the objectives (Diamond *et al.*, 1996). However, the degree of comparability of two methods is usually unknown because no direct comparisons have been made (Diamond *et al.*, 1996). When SASS5 and IBMWP methodologies are compared, their different mesh size, sampling intensity and segregated habitats do not seem to influence on the final results, and a similar community composition and water quality is found. Because more disturbed sites were sampled in Spain than in South Africa, no coincident patterns in water quality are present between both countries, although both methods appear to work well in disturbed and undisturbed sites. For Spanish sites, only one site (MONT) may be qualified as a pristine locality with a high biotic quality with a lower IBMWP in LV habitats compared with RS habitats, which is similar to what have been found in South African samples where mostly of sites are pristine. On the other hand, in South Africa, only the site EC displays a low value of biotic index with similar values between all sampled habitats, as happen in most of the Spanish sites. Consequently, both methods are equally sensitive to water quality as they provide similar results in distinguishing high and low quality sites in Spain and South Africa, when all habitats are used. The lower quality values present in Spanish sites can be related to two factors: some pollution and poor river habitat conditions. In several studies, Prat *et al.* (1997, 1999) reported a fair biological quality in B22, B25 and B28 because the human alteration of the Tenes and Ripoll basins. On the other hand, B24 have also an impoverished macroinvertebrate assemblage although it has been considered as a reference site in Bonada *et al.* (in press). This locality has a temporary condition and a low diversity in substrate composition (with bedrock as a predominant substrate) (Prat *et al.*, 1997, 1999) that could affect to the establishment of a rich community (Lenat & Barbour, 1994). In that sense, in a nearby area, Bonada *et al.* (2000) also found low quality values in non-impaired sites because of the physical structure and temporality, but not as consequence of impaired water quality.

Although no differences are found in biotic indexes among methods, a 32% of dissimilarity (Bray-Curtis coefficient) is found between the macroinvertebrate assemblages found with Spanish RL and South African SV methods in both areas, which may be related to differences in mesh size used, sampling and sorting intensity, experience in the area or spatial variation in the macroinvertebrate distribution. In average a slightly higher number of taxa is found with RL methodology compared to SV in Spain, and lower taxa richness in South African samples (Figure 3) what could be related to the familiarity of each researcher with the macroinvertebrate fauna of her country. For example several taxa difficult to find (by size or behavior) can be missed by the non-native researcher in the foreign country, as some Psychomyiidae that live in carved sticks or other cryptic taxa living in specific microhabitats (Lenat & Barbour, 1994). In that sense, we have found that families collected only by the native researcher in its own country and not for the other are rare or infrequent (e.g., Dixidae, Belastomatidae, Psychodidae) or have been found in low abundance in the sampling period (e.g., Ancylidae, Gammaridae, Heptageniidae, Gerridae or Hydroptilidae in Spain). In other cases, because of quite cryptic families (e.g., Hydroptilidae) have been found in both countries by local researches, we can accept that the highest number of exclusive taxa found by native researchers in its own area might be by chance, and not because of their different degree of experience in each country.

The kind and number of habitats to be sampled in a RBP have been widely discussed (Resh *et al.*, 1995; Hewlett, 2000). Plafkin *et al.* (1989) proposed that the “most productive habitat” should be sampled and Lenat (1988) suggested the high current habitat with “structure”. Specially in pristine sites, we found that riffles (R) or stones (S) seem to be the most productive habitats to give an optimum biotic index, and other authors have pointed out that a sampling based on riffles should be enough (Parsons & Norris, 1996) because usually these habitats provide the highest number of taxa (Carter & Resh, 2001). However, the high annual variability of mediterranean rivers implies that riffles may disappear in some cases with only pools remaining in summer (Gasith & Resh, 1999). Therefore, the use of only one habitat in these streams cannot be recommended. In that sense, a multihabitat protocol integrating all habitats, as in SASS5 and IBMWP, is preferred (Stribling *et al.*, 1993; Resh *et al.*, 1995; Bonada *et al.*, Chapter 1).

In pristine conditions, riffle habitats (R) are equivalent to stones (S) indicating a low influence of the stones-out-of-current habitat, and both contributed significantly to the final score. Dallas (1997) comparing the influence of habitat on the SASS4 scores found that stones in current represent 70% of the SASS4 of the relative percentage to the total calculated for the site, whereas stones out of current only contribute to the 46%. In impaired conditions (all sites except MONT in Spain, and EC in South Africa) differences between habitats are not significant. Number of taxa and biotic index of R and S is lower than in pristine sites, but not in L and V where similar values are found in all sites in Spain and South Africa. Consequently, in impaired conditions, R and S habitats are more affected for pollution than L and V, and the lower values of biotic indexs may be associated to the decrease of the family’s biotic scores as can be seen in the IASPT and ASPT values. This phenomenon could be related with the high velocity of the water in riffles and stones that increases its vulnerability to pollutans because bounday-layer on macroinvertebrates become thinner (but see Lowell *et al.*, 1995). In fact, Logan & Brooker (1983) pointed out that the effects of pollution by solids were higher in riffles than in pools, and consequently suggest using both habitats to assess water quality.

Decisions about what sampling gear to use in a RBP also have been discussed in literature. Kick and "sweep" nets are preferred in front of Surbers or Hess samplers (Storey *et al.*, 1991; Lenat & Barbour, 1994). In that sense, kick method has been recommended in biomonitoring surveys (Storey *et al.*, 1991) providing semiquantitative or qualitative data. However, multiple methods have been used, and the most convenient should be selected according to the objectives desired in the study (see Rosenberg, 1978; Elliot & Tullett, 1978, 1983). The same happens with mesh size, as a range of size from 200 to 1000 μm has been used in biomonitoring. In our case (and contrary to many studies) because of no differences in biotic indexes are found using 250 and 1000 μm mesh size, if the objectives of the study are only to assess water quality, a more coarse mesh size may be used. An intermediate mesh size of 500 μm have been proposed by the sampling standardization normative ISO in Europe (AENOR, 1995), and is the most common used in the US (Carter & Resh, 2001). Probably, the fact that family level is the taxonomical unit used might explain similarities in results using different mesh sizes, because of the smallest animals from many families may be lost (e.g. Chironomidae) but the larger ones remain in the sample.

Sampling and sorting efforts are different between SASS5 and IBMWP. In the former, time constrains the sampling and sorting intensity, whereas in IBMWP sampling and sorting continues until no more new taxa is added and all community richness is collected, being the result a bigger sample size. However, this difference in sampling size between protocols do not affect to the biotic indexes values, which agree with the results found by Metzeling & Miller (2001) comparing SIGNAL values between different sampling sizes in Australia. Consequently, because of our results indicate that in pristine and impaired sites both methods are equally applicable, the most efficient method in time consuming could be satisfactorily used in both countries to assess water quality. In pristine conditions SASS5 could be more advantageous because its time limitation and only one sample is required. However, Dallas (1995) sampled several times using the SASS5 procedure and found that in a pristine site in one sample only 28% of total taxa was recorded, whereas in a impaired site, one sample provide 45% of taxa. The same study shows that 4 samples are required to get the 95% of taxa, and consequently, SASS5 values increase with the sampling effort. Thereby, if the objectives are to go further than a biological assessment (autoecological or faunistic studies), probably the IBMWP methodology yield better results in pristine conditions, as a best representation of all community (and sizes) is provided, including rare taxa. In that sense, Cao *et al.* (2002) demonstrated using field and simulated data sets that the total taxa richness found with a fixed sample size (e.g., using a sampling methodology constrained by time or space) varies between sites, and consequently sampling until no more taxa is added (i.e., until the highest autosimilarity between samples is achieved) imply a highest representativeness of the community.

Although, in either SASS5 or IBMWP the taxonomical resolution used is the family level, in SASS5 Baetidae or Hydropsychidae scores are disaggregated according to the different species found, as both families have tolerant and intolerant species (Chutter, 1998). However, although lower taxonomic resolution yields good information (Furse *et al.*, 1984; Resh *et al.*, 1995) field identifications of different species are usually difficult at those levels and a specific training is required to obtain good results.

A lot of data is available about biological assessment, but the different methods used make comparisons uncertain (Diamond *et al.*, 1996). Different procedures can yield similar predictions, but this must to be known to test the applicability of one method in another country, and to redesign each method depending on the objectives desired. For example, Solimini *et al.* (2000) comparing IBMWP and the Italian EBI (Extended Biotic Index) (Ghetti, 1995) found that IBMWP was more sensible to biotic quality in Tibre River (Italy) and suggest the use of it respect EBI. RBPs have been designed to be efficient, easy and rapid to apply (Resh & Jackson, 1993; Resh *et al.*, 1995). To perform that, the sampling and processing of samples is simplified without a loss of information (Resh *et al.*, 1995; Barbour & Gerritsen, 1996). SASS5 and IBMWP protocols provide similar information in South Africa and Spain, but SASS5 is a more cost-effective protocol in terms of time than IBMWP. However, Guadalmed IBMWP protocol has been designed to provide complete information of the macroinvertebrate community present to perform further autoecological studies or predictive models. Because of their similar applicability to perform bioassessment in both countries, redesigns of one method with properties from the other can be possible to get the established objectives. However, although both methods provide similar information in bioassessment in pristine and impaired sites, they should also be contrasted also in other sampling period or regions. For example, if the sampling was performed in temporary sites, just after the drought period, different mesh size could affect the final results, as the community of pools are composed of small organisms (Williams, 1987, 1996) that could escape in a coarse mesh size.

Nowadays, both countries take similar future directions. The development of the "River Health Program" in South Africa or the implementation of the "Water Frame Directive" in Europe are based on the assessment of ecological status using reference conditions and referred to ecoregions or ecotypes. These policies will provide an assurance of how aquatic ecosystems must be managed to improve their ecological status. Both RBPs methods (SASS5 and IBMWP) are adequate to fulfill these objectives.

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Chapter 3

MEDITERRANEAN CLIMATE RIVERS OVER THE WORLD: convergences and divergences between regions[1].

INTRODUCTION

Mediterranean regions and climate

There are five regions over the world present a mediterranean climate (called med-regions). They are located between 32º-40º N and S of the Equator, in the west side of continents (Aschmann, 1973a): Mediterranean Basin, California, Chile, South Africa and Australia (the South-West and South). All these areas represent between 1% and 4% (di Castri, 1981; Mooney, 1982) of the earth surface (Figure 1). However, there are discrepancies among geographers, physics or biologists in the description and delimitation of extension of mediterranean climates (Nahal, 1981).

The mediterranean climate is defined in terms of precipitation (di Castri, 1973a) and temperature (Aschmann, 1973a), and it is characterized by a high seasonality (Paskoff, 1973; Daget & Michel-Villag, 1975) summarized as hot and dry summers and cool and wet winters (Köppen, 1923). Winter temperatures are mild (7-13ºC) with frosts and snow infrequent,

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[1] Mediterranean is written with “M” when is referred to the Mediterranean Basin, and with “m” when it speaks of the climate.

whereas summers are hot with a mean temperature of 14-25°C (Paskoff, 1973). On the other hand, precipitation it is highly variable along and between years (Paskoff, 1973; Nahal, 1981), implying a high climatic heterogeneity either along time and space (Mount, 1995). The annual range of precipitation goes from 275 to 900mm/y, although several authors define the clime only using the minimum (see Conacher, 1995; Conacher & Sala, 1998). Most of rainfall falls during winter months, and this is one of the key elements to distinguish between mediterranean, temperate and subtropical climates (Dept. Land Affairs, 1994). According to Aschmann (1973a) more than 65% of annual rainfall should fall in winter, although in some areas this is not as strict (Köppen, 1923; Specht, 1979) with important spring and autumn rains (Southern California and Southern Europe —Miller, 1983). During summer, a drought period is present with length and intensity variable between years (di Castri, 1973a, 1981).

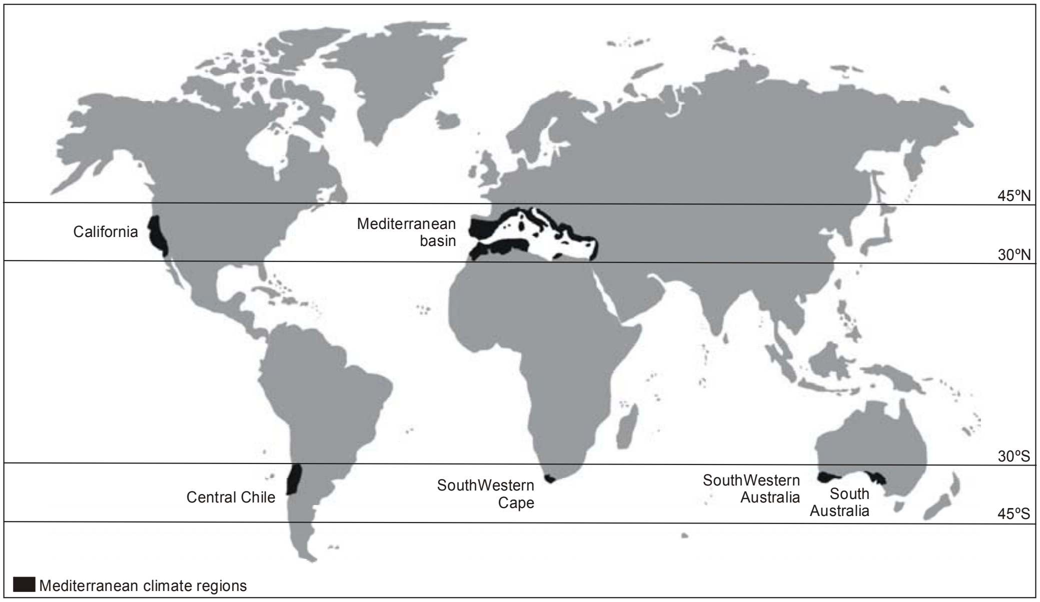


Figure 1. Map of the distribution of mediterranean climate over the world.

Although there are many common climatic characteristics among med-regions, local climate is modified by orography, altitude, orientation from coast line, continent and oceanic influences... (Aschmann, 1973a; Conacher & Conacher, 1998), and therefore several microclimatic patterns can be established (Nahal, 1981; Daget *et al.*, 1988). Köppen (1923) distinguishes between hot and cold summers, and Emberger (1930, 1955, and 1971) defines 6 types of subclimates according to its humidity and the winter severity: subdesertic or periarid, xeromediterranean or arid, termomediterranean or semiarid, mesomediterranean or subhumid, submediterranean or humid and subxeric or perhumid. However, from these subclimates Di Castri (1973c) distinguished an "eumediterranean" subclimate which would be equivalent to the semiarid and subhumid subclimates, with a precipitation range of 275-640mm/y.

Mediterranean climate is located between the temperate and dry climate areas (see Dallman, 1998), and both regions have influenced strongly the mediterranean climate and its present biota (di Castri, 1981; Herrera, 1995). Relationships with these adjacent climates are variable between regions (di Castri, 1981). For example, summer precipitation is higher in South Africa and northern Mediterranean Basin because of their proximity to tropical and temperate regions, and lower in Chile because of Atacama Desert influences (di Castri, 1981).

Mediterranean biota and humans

Mediterranean climate originated in the Pliocene, 3.2 My ago (Alxelrod, 1973; Suc, 1984), and therefore is a young climate in geological terms, younger than part of the biota found in these med-regions (Raven, 1973). As a consequence, some lower vertebrate, invertebrate and plant distributions are homogeneous, reflecting the patterns established during the Mesozoic, before the breakup of the continents and the formation of the mediterranean climate (Deacon, 1983; Herrera, 1995), or the later connections between regions (Nilsen, 1978; Cooke, 1972). Once the climate was formed, similar selection forces acted in the configuration of the mediterranean biota (Johnson, 1973), and therefore, a high similarity between regions should be expected (Mooney, 1982). However, mediterranean areas in the world show an important variability in ecosystems, because of geographic, microclimatic, topographic, physiographic, litologic and historic aspects have contributed to the present faunal and floral distributions (di Castri, 1981). Several authors suggest 4 origins of the mediterranean biota (di Castri, 1991):

- Species developed *in situ* before the mediterranean climate formation.
- Species developed after the mediterranean climate was established.
- Species developed outside the mediterranean regions but that settled in these areas posteriorly.
- Invasive species from human impact.

When biota is compared among med-regions, all these possible origins must be considered and specially the historical or environmental factors (di Castri & Hadley, 1985; di Castri, 1991).

When first explorers arrived into the Cape region, central Chile, California and Australia, noted a high resemblance between these regions with the Mediterranean Basin (di Castri, 1981). However, the biogeographical concept of mediterranean biome was established a century later by Grisebach (1872), Drude (1890) and Schimper (1898), based on the similarities between vegetation in mediterranean areas. First comparative studies in these med-regions derived from botanical aspects (Spetch, 1979; Specht & Rayron, 1957; Specht, 1973; Cody & Mooney, 1978) revealing a high similarity in plant morphology and structure (Mooney and Dunn, 1970), with a sclerophyllous and evergreen vegetation (Kummerow, 1973; Mooney, 1977, 1982; Rundel, 1988). Duration of the summer drought and the cold in winter seem the ecological factors more likely to provide this similarity (Aschmann, 1973a; Nahal, 1981; Orshan, 1983; Miller, 1983). Both phenomena imply a continuous and predictable natural disturbance, where the evolution took place (Stanford & Ward, 1983), and developing plant communities with common characteristics with different names: chaparral in California, maquia or matorral in the Mediterranean Basin, matorral in Chile, fynbos in South Africa and health or mallee in Australia (Naveh & Whittaker, 1979). Some studies indicate that this type of vegetation and structure is not exclusive from the mediterranean region, with some extensions through areas with high summer rainfall in the east of Australia (Specht, 1979), Mexico (Muller, 1939) or east Africa (Rundel, 1988).

In spite of these similarities, some differences are present because of local factors as human impact, soil nutrients (Specht, 1979; Mooney, 1982; Specht & Moll, 1983), humidity (Beard, 1983), natural history (di Castri, 1973b) or landscape orography (Cody, 1973; Mooney, 1977; di Castri, 1981). However, as a general rule, mediterranean regions are richer in species that the adjacent ones (e.g., temperate or dry) (Raven 1973; Deacon, 1983), with a high endemism rate (Cowling, 1992) and very heterogeneous in space and time in terms of community composition and structure (di Castri, 1973, 1981).

Comparisons of floral and faunal communities between mediterranean regions are not easy because in some cases a high number of taxa with different ages of origin coexist (di Castri & Mooney, 1973). Despite of those difficulties, affinities in faunal communities between the med-regions have been described in numerous studies. Most of them focused on lizards (Sage, 1973; Fuentes, 1976), birds (Cody, 1973; Herrera, 1995) or terrestrial arthropods (di Castri & Mooney, 1973; Majer & Greenslade, 1988; Stamou, 1998), but few are performed in aquatic arthropods, although some suggestions have been made (Gasith & Resh, 1999).

In the mediterranean climate areas, the water high seasonal stress condition implies that organisms present some specific adaptations. Consequently, most of the affinities it can be found between these areas are related to physiological, morphological or behavioral adaptations (e.g. in artropods —Stamou, 1998) to avoid the severity of drought and its seasonality and interannual variability. In that sense, resilience and resistance are common attributes found in the elements of the mediterranean biota (Grubb & Hopkings, 1986), being the first more frequent (Fox & Fox, 1986). These adaptations give higher probability of permanence to mediterranean communities to the seasonal predictable natural disturbances (Aschmann, 1973; Orshan, 1983).

In addition to this harsh natural conditions, mediterranean climate areas have been exposed since many years ago to human disturbances (Mooney, 1982), although the human impact differs among med-regions because of the different time of human colonization (Aschmann, 1973b; Fox & Fox, 1986). Probably, fire is the main disturbance in these ecosystems (Miller, 1983; Keely, 1986), altering nutrient availability and influencing on speciation (Cowling, 1987) with fire-dependents and resilient plants (Kruger, 1979ac; Fox & Fox, 1986; Keely, 1986). For instance, in the South African fynbos several plants need the fire to reproduce; in Australia some tree are adapted to fire and its frequency and intensity; and even in Chile with a weak fire history, some adaptations to fire are present (Grove & Rackham, 2001).

Trabaud (1981) points out that med-regions are unique to have been affected by human activities for ages, as the introduction of non-native plants and animals, agriculture, cattle, urbanization, salinization... (Conacher & Sala, 1998). Because of the impact of all these activities, med-regions are characterized by lost of natural vegetation, soil salinization, water pollution and high erosion (Conacher & Sala, 1998). These consequences can be more or less important in each region, and topography, lithology or the climate itself can accelerate the erosion and the land degradation (see Conacher & Sala, 1998). Hence, an increase of temperature by climate change could have important consequences in the mediterranean ecosystems, enhancing the water stress in the arid and semiarid areas or prolonging the growth season in the alpine regions (Le Houérou, 1990).

Mediterranean rivers

Rivers influenced by this climatic heterogeneity in temperature and precipitation regimes are considered mediterranean rivers (Gasith & Resh, 1999). Because in the mediterranean climate several microclimates can be distinguished (Nahal, 1981; Daget *et al.*, 1988), we understand that several river typologies can also distinguish in med-regions: from mountain permanent stream in the most humit areas to ephemeral ones in the most arid ones. In Plates 1 to 5 the main features of med-rivers in the five areas in the world are summarized.

River discharge is related to rainfall patterns (depending on the vegetal cover, temperature, evaporation, relief and soils) (Beckinsale, 1969; Alexander, 1985), and therefore, mediterranean rivers are characterized by yearly variable discharge regimes, with a maximum peak in winter a minimum flow in summer (Bradbury, 1981; Gasith & Resh, 1999). Moreover, an interannual variability is also present carrying out changes in river flow and freshwater communities along time (McElravy *et al.*, 1989; Resh *et al.*, 1990).

Frequently, rainfall in mediterranean rivers is presented as intense storms with a variable frequency, which implies frequent floods in the rainy season, especially in small and steep basins (Paskoff, 1973; Camarasa & Segura, 2001). On the other hand, in the dry season, because of the lack of precipitation and the high evapotranspiration, temporality in small streams can be common (Thrower & Bradbury, 1973; McElravy *et al.*, 1989; Conacher & Conacher, 1998; Gasith & Resh, 1999; del Rosario & Resh, 2000; Camarassa & Segura, 2001), except in cases when discharge is maintained by the influence of ground water (Vidal-Abarca *et al.*, 1996) o by snow-melt when streams are feed by high mountains (Beckinsale, 1969).

As a result of this discharge pattern, aquatic ecosystems are highly subject to biannual hydrologic disturbances, characterized by the alternation of floods and droughts (Molina *et al.*, 1994). This general pattern may be considered as predictable but with a variable frequency and intensity (Gasith & Resh, 1999), being droughts more predictable than floods (Vidal-Abarca, 2001). Permanent rivers may be found in areas with a relative high and predictable rainfall, whereas intermittent or ephemeral ones are located in areas with a low and uncertain rainfall (arid and semiarid zones) and without connection to main aquifers, being completely rainfall dependents (Vidal-Abarca, 1990). Permanency or temporality are functions of precipitation, microclimate patterns and freatic level, although other structural and local factors (e.g., substrate) can be important (see Bonada *et al.*, Chapter 5).

The effect of this variability in discharge over to biological community has been studied by several authors (see Gasith & Resh, 1999). In general, numerous adaptations to droughts (see Williams, 1985) and floods (Statzner *et al.*, 1988; Resh & Solem, 1996) have been found. In early summer, as long as the river is drying up and habitat change, there is a variation in composition and abundance in aquatic biota (Gasith & Resh, 1999). Later, autumn and winter floods connect the isolated reaches in the temporary rivers and provoke spates in temporal and permanent streams washing out downstream algae and macroinvertebrate communities. After the flood, communities may be reestablished relatively fast (Badri *et al.*, 1987; Vidal-Abarca *et al.*, 1992; Pires *et al.*, 2000). According to the variability of the discharge along the year the rivers and streams can be classified into three groups (Bonada *et al.*, Chapter 5): permanents with running water in summer, intermittents with isolated pools in summer and ephemerals that are totally dried up after few months (even weeks) of the flow cessation.

This variety in characteristics in mediterranean rivers, provided by natural disturbances, is the origin of a high floristic and faunistic diversity (Prat *et al.*, 2000a) and endemism (Gasith & Resh, 1999). However, these ecosystems are very sensitive to a loss of diversity, because the seasonal variability of the mediterranean climate makes the fluvial systems more vulnerable to pollution (Gasith, 1992; Davies *et al.*, 1993; Sabater *et al.*, 1995; Gasith & Resh, 1999). Consequently, Mediterranean rivers are highly affected by human disturbances yielding a very poor ecological status (Prat, 1993; Prat & Munné, 2000). Moreover, in nowhere else in the world the aquatic fauna is declining as rapidly than in mediterranean regions (Moyle & Leidy, 1992) because of the non-native introductions, high population density, limited availability of water and unsatisfactory management.

Johnson (1973) postulated that although similar biota between isolated areas is possible because of a common ancestor, usually the environmental conditions have actuated more or less equally over the evolution of the biota, and so it is not likely that the convergence characteristics are reached by chance. Therefore, because the mediterranean climate shares similar kind of environments, macroinvertebrate communities should also be similar (Gasith & Resh, 1999), as the vegetation (Mooney and Dunn, 1970) or lizard communities are (Fuentes, 1976). Several ecological freshwater studies have been done comparing different biomes, climates or continents (Vinson & Hawkins, 1998) looking for convergences and divergences (Moyle & Herbold, 1987; Lamoroux *et al.*, 2002), but few of them are focused on comparisons between mediterranean rivers (see King *et al.*, 1988), although the numerous local studies performed in these areas (see Gasith & Resh, 1999). Studies about ecological convergences in mediterranean ecosystems are required to determine the applicability to another area of the ecological principles derived from local studies (Kruger *et al.*, 1983).

Because communities have different structure, composition and responses may change at different scales of observation (Kotliar & Wiens, 1990; Tonn *et al.*, 1990; Wiens *et al.*, 1993; Peckarsky *et al.*, 1997). Choosing the appropriate scale of study have been a problem for many stream ecologists (Peckarsky *et al.*, 1997) and thereby, several authors recommend performing studies at multiple scales of observation to understand patterns and processes of biological communities (Peckarsky *et al.*, 1997; Poff, 1997) and facilitate convergences and divergences between regions (Tonn *et al.*, 1990; Samuels & Drake, 1997). Thus, the aim of this paper is to present convergences and divergences among mediterranean climate rivers over the world at two scales of observation: regional and local (including reach and habitat). The objectives of the study are:

1.- To compare faunistic composition of macroinvertebrates at family level between all med-regions, in order to find if differences because of historical reasons may be important for ecological purposes.
2.- To study if the effect of temporality and habitat characteristics over the macroinvertebrate community are similar in four med-regions, despite of biogeographical differences.
3.- To establish convergences and divergences between the med-regions according to different aspects of the aquatic ecosystems.

METHODOLOGY

The faunistic assemblage in mediterranean rivers

In this Chapter, the assemblage of macroinvertebrates in a region is defined as the total taxa that could be found in any stream of the area at family level at any time (accumulated assemblage). Family level was preferred to simplify comparisons and to avoid data “noise” from genus or species level because of their high biogeographic variability. Moreover, in some areas the genus and species of some families (e.g. Chironomidae) are poorly known or difficult to identify. In some cases, as Oligochaeta and Hydracarina, the order level was used instead of family because taxonomic difficulties. The list of families recorded in each med-region has been obtained using personal data, references and non-published reports of freshwater researchers in each area. Chris Madden from the Australian Water Quality Center and Ricardo Figueroa from the Universidad de la Concepción provided unplublished data from South Australia and Chile, respectively.

Effect of the temporality and habitat on macroinvertebrates

Sites studied

Between 1999 and 2002 the former author made several studies in the mediterranean areas of California, South Africa, SWAustralia and the Mediterranean Basin. In all cases, the sampling period was spring, when the rivers were flowing to enable comparisons between areas.

Table 1. Number of sampling sites in med-regions.

	Med-Basin	**California**	**South Africa**	**SW Australia**
Total reference sites	42	10	12	9
Total R/L sites (reference)	8	10	12	9
Permanent reference sites	32	8	8	6
Temporary reference sites	10	2	4	3

As possible, many types of rivers in headwaters and downstream reaches were sampled, although sampling sites did not cover all the extension of each mediterranean region. Several permanent and temporary reference sites were selected and sampled in all four med-regions. Sites were identified as temporary if the river usually remains intermittent (disconnected pools) or dries up in summer or at least it was dry the summer before the study, whereas sites known to have continuous flow along year were qualified as permanents. Table 1 summarizes the number of sampling sites for each mediterranean sampling area.

Sites in Mediterranean Basin: Spain

Data from spring 1999 was obtained from the GUADALMED project (see Chapter 1). From the 157 sites sampled by the Project, 42 reference localities were used according to the criteria established by Bonada *et al.* (in press b). Sites are distributed along the mediterranean coast of Spain, including the Balearic Islands, and they belong to 11 basins: Besòs Llobregat, Mijares, Turia, Júcar, Segura, Aguas, Almanzora, Guadalfeo, Adra and Pollença (Figure 2). Information about the characteristics of these basins, typology of sites, riparian vegetation and habitat characteristics is found in Robles *et al.* (in press), Bonada *et al.* (in press a), Suárez *et al* (in press) and Pardo *et al* (in press). In general terms, sampling sites cover wide types of rivers, as was showed by Bonada *et al.* (in press) from small alpine rivers in Catalonia and Granada to karstic systems in Catalonia, Mallorca or Almería and ramblas in Murcia and Almería. Reference localities with disconnected pools in spring 1999 were non-considered in the analysis. Rainfall accumulated one year before sampling was 507.6 mm in an area near sampling sites (Vallès Oriental, Catalonia).

Sites in California

10 sampling sites in Northern California (Figure 2) were sampled in spring 2002, belonging to 3 of the 5 ecoregions established in California by Bailey (1995): 3 located in the west side of Sierra Nevada in the “Sierran steppe, mixed and coniferous forest”

ecoregion; 4 in “Northern California Coastal redwood forest and steppe” and 3 in “Southern California coastal chaparral woodland, coniferous forest and meadow”. Localities in the Sierra Nevada are reaches with fast flowing waters, in forested basins, medium slopes and substrates with boulders and cobbles. The riparian vegetation is dominated by *Alnus* sp., *Salix* sp. (3 species), *Populus* sp. with some *Pinus lambertiana* and *Pseudotsuga menziesii* from the adjacent coniferous forest. The algae *Nostoc* sp. is abundant and frequently is present in symbiosis with Chironomidae larvae. In coastal ranges, rivers have high slopes with coarse substrate except in the longest rivers (as San Geronimo River) where gravels, sand and bedrock are important. Riparian vegetation is composed by *Quercus lobata, Alnus* sp*., Corylus cornuta, Sequoia sempervirens* and *Umbellularia californica*. Through the south and near the coast, sampled rivers are short, small and steep. Substrates are similar to the ones in the northern coasts. The riparian vegetation is composed by *Quercus lobata*, *Platanus racemosa, Juglans hindsii, Populus* sp., *Salix* sp*., Alnus* sp., *Corylus cornuta* and *Umbellularia californica*. Rainfall accumulated one year before sampling was 572.64 mm in an area near sampling sites (Napa valley).

Sites in South Africa

South African survey was performed in spring 2000. Sampling sites were located in three different places (Figure 2): 3 in the Table Mountain ranges, 8 in the area of influence of the Franschhoek and Drakenstein Mountains, and 1 in the low Palmiet close to the sea, in the area called Kogelberg State Forest Reserve. Table Mountain sites have a high slope, with boulders and cobbles dominant, whereas low slopes characterize the rest of sites. In all cases, dominant vegetation is mountain fynbos, although near the river individuals of the riparian shrubs *Metrosideros angustifolia* or *Brabejum stellatifolium* are present. In headwaters, the macrophyte *Isolepes* sp. is abundant with mosses and Palmiet (*Prionium serranum*). Rainfall accumulated one year before sampling was 569.2 mm in an area near sampling sites (Cape Town).

Sites in SW Australia

A total of 9 sites in three catchments in the south of Perth were sampled in spring 1999: Serpentine River, Drakes Brook and Brunswick River (Figure 2). They are located on the Darling Plateau, where the karri forest is present providing a very forested basins by several *Eucaliptus* species and with a shrubby undergrowth. Near the river, individuals of *Melaeuca* sp. are present. Gravels, sand and silt, with bedrock and boulders scarce, dominate the substrate of the rivers. Rainfall accumulated one year before sampling was 774.6 mm in an area near sampling sites (Perth).

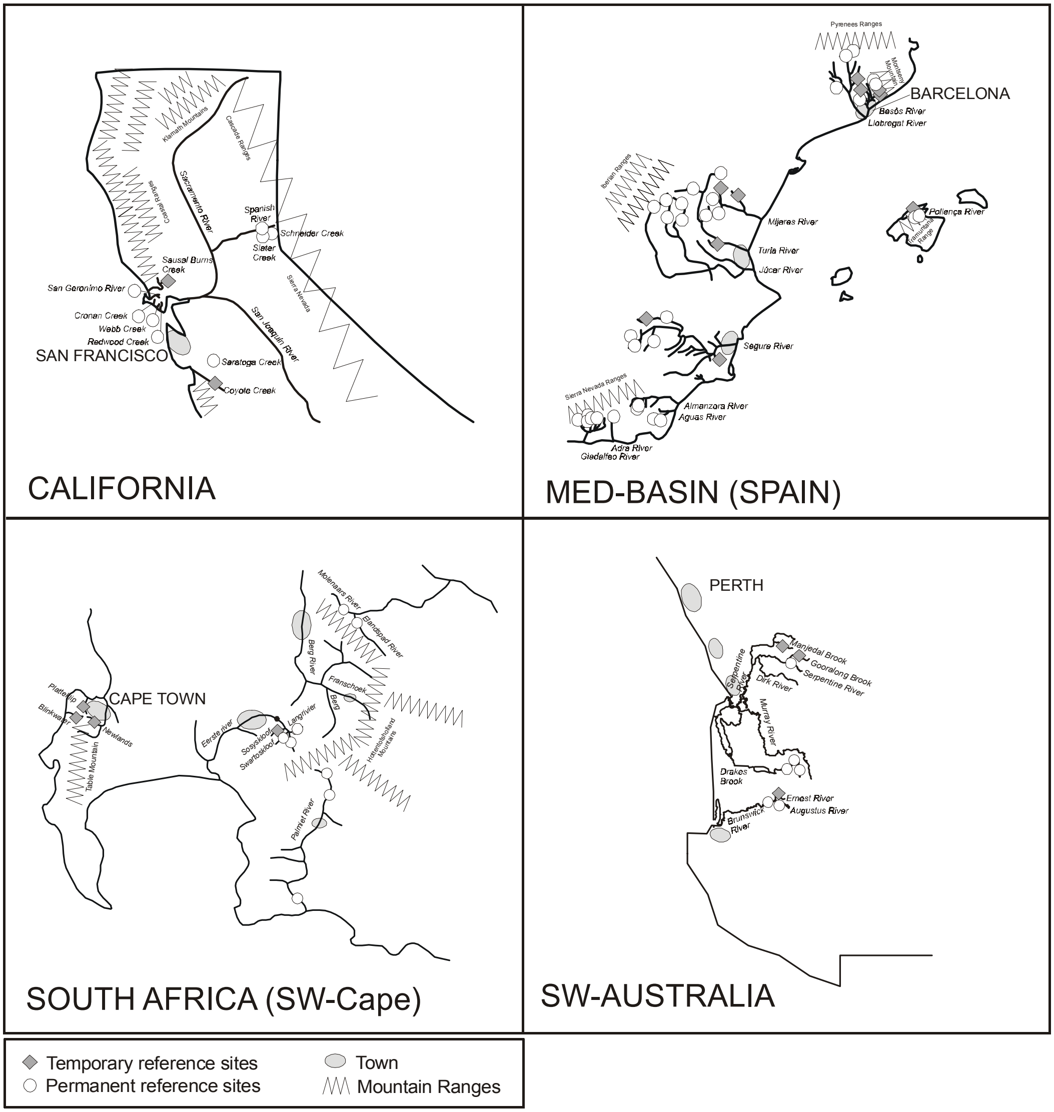


Figure 2. Sampling sites in California, Spain, South Africa and SWAustralia.

Sampling procedure

All reference sites were sampled using the Protocol 2 developed by the GUADALMED project (see Bonada *et al.*, Chapter 1; Jáimez-Cuéllar *et al.*, in press). This Spanish project attempts to assess the ecological status of the Mediterranean rivers according to the guidelines of the Water Frame Directive (WFD) (European Parliament and Council, 2000). The first stage of the

Project was to establish a standardized methodology to be used as a Rapid Bioassessment Protocol (RBP). The protocol was initially developed by Prat *et al.* (1997, 1999, 2000b), and has been tested and established later for all sampling sites in GUADALMED Project. Although GUADALMED Protocol was conceived as a bioassessment method, the fine mesh size used (250 µm) and the absence of sampling restrictions comparing with other procedures, allow us the use of this Rapid Bioassessment Protocol (and specially Protocol 2) in macroinvertebrate community studies (Bonada *et al.*, Chapter 2).

In each site, several physical and chemical parameters were measured *in situ* as pH, oxygen (mg/l and %), temperature, conductivity and discharge. Two indexes developed in the GUADALMED Project were applied to check for the applicability of Spanish methodology in other mediterranean areas. The first one is the QBR, an index that to assess riparian vegetation quality (see Munné *et al.*, 1998, 2002; Suárez and Vidal-Abarca, 2000 and Suarez *et al.*, in press). The second one is the IHF designed to characterize habitat diversity (see Pardo *et al.*, in press), a method with some similarities with the RBP's method used in EEUU (see Barbour *et al.*, 1999).

For macroinvertebrates, the GUADALMED methodology consists in collecting samples separately from riffles (R) and lentic (L) habitats with a circular kick net of 250 µm mesh size. Each sample is examined in the field and successive samples in both habitats are taken until no more families are found, to collect a representative sample of the community. Several invertebrates seen in the field but not taken in the sample were also recorded, as the large Heteroptera and Coleoptera. Samples were preserved in alcohol 70% and sorted in the lab, to avoid errors in identifying taxa. Macroinvertebrates were identified at family level (except Oligochaeta and Hydracarina) and a rank of abundances was recorded for each taxa: 1 from 1-3 individuals, 2 from 4-10, 3 from 11-100 and 4 for more than 100 individuals. Thus, data were semiquantitative and all the statistical analysis has been done according to it.

Data Analysis

Macroinvertebrate community assemblage in all med-regions

A Non-metric Multidimensional Scaling (NMDS) was applied to the presence/absence matrix with all taxa in med-regions. This ordination method preserves the distances between objects, plotting dissimilar objects far from the similar ones (Legendre & Legendre, 1998). On the other hand, the NMDS method is a method not based on eigenvalues, and the final axes are arbitrary without enclosing the explained variability. Because of the presence/absence data, Jaccard coefficient was selected as a binary method to calculate distances between variables. This index is focused in checking similarities between variables, as double 0 are excluded. The statistical program used was the PCORD (McCune & Mefford, 1999).

Differences and similarities between all reference sampling sites in med-regions

Physical, chemical and structural features

Once reference sites were established, a Principal Component Analysis (PCA) was performed to check for differences in environmental variables measured. Prior to analysis, these variables were standardized, tested for autocorrelation with r-Pearson. Skewness values for each variable were also calculated to avoid variables that could bias the analysis (Legendre & Legendre, 1998). PCA is a multivariate ordination analysis based on the Euclidean distance that let to study relationship between objects (sites) and descriptors (variables) in a reduced space. The CANOCO Program vs.4 (ter Braak, 1998) was used to compute the analysis.

Macroinvertebrate's abundances

Common taxa in all sampled regions were used to check for differences between the relative abundance between reference sites in the 4 sampled med-regions. Because in each med-region a different proportion of temporary sites respect permanents were sampled, only permanent sites were used to check similarities and differences in abundances. A non-parametric Kruskal-Wallis test was computed with a relative abundance (in %) data matrix and using sites in med-regions as replicates because its reference condition (Norris, 1995). Previously, data was tested to normality with the Shapiro-Wilk's test (that have a good power properties compared with a wide range of alternative tests), and to homogeneity of variances with the Barlett's test. The STATISTICA Program was used to perform the analysis (Stat Soft, 1999).

Effect of temporality

To test if differences between permanent and temporary sites were higher than between med-regions, a Bray-Curtis cluster with flexible clustering (β=-0.25) was performed using all common taxa. For each med-region, macroinvertebrate relative abundance matrix in permanent and temporary sites was compared using a MRPP analysis (Multi-response Permutation Procedures). This method is a nonparametric method for testing multivariate differences among pre-defined groups (permanent or temporary sites), providing the statistic A and a p-value obtained by permutation (999 runs) as result. Because its non-parametric condition this method is more appropriated than MANOVA in comparisons of data matrixes that involve species abundances including many zero values.

Several metrics were tested to check for differences between flow conditions: number of taxa, relation EPT/OCH, number of Diptera taxa and number of non-insect taxa. Differences were tested with a Kruskal-Wallis test (after test for normality and homogeneity of variances). Further, an IndVal method (Dufrêne & Legendre, 1997) was performed to explain the meaning of the differences found between permanent and temporary sites and to determine the indicator community of each flow condition in med-regions. This method checks the indicator value for each taxon in the defined environmental conditions (permanent and temporary sites). A Monte Carlo permutation test with 9999 permutations was used to test for significance of each indicator value. This analysis has several advantages over the widely used TWINSPAN (Hill, 1979) as the possibility to obtain an indicator value for each taxon that is independent of abundances of other species (Dûfrene & Legendre, 1997). Only the taxa with more than an indicator value (IV-value) of 25 were kept (Dûfrene & Legendre, 1997). In order to find the degree of similarity between two med-regions, the percentage of common taxa in those two regions that have a similar pattern was calculated.

The statistical program PCORD (McCune & Mefford, 1999) was used to compute MRPP, IndVal and Bray-Curtis analysis whereas STATISTICA was employed for the non-parametric tests.

Effect of habitat

Similar analysis performed among riffle and pool habitats were applied to permanent and temporary sites. Thereby, a Bray-Cluster was also performed with common taxa, to test if biogeographical differences were more important than the habitat effect. Further, MRPP test, IndVal method and % of similarity between pair-regions were performed to check for differences among riffles and pools habitats and their indicator community in all mediterranean regions.

RESULTS

Macroinvertebrate community assemblage

A total of 212 different taxa were used to perform the analysis between med-regions. Most of taxa were at family level except Oligochaeta and Hydracarina that were used at a higher taxonomical level. Figure 3 shows the result from NMDS analysis. Macroinvertebrate community is highly similar between the northern hemisphere med-regions of California and Med-Basin, with a 94% of similarity, while in the southern hemisphere there is an important variability in the macroinvertebrates community. South African community is the nearest to the northern hemisphere, sharing 65% of the taxa, while the Chilean area seems to be the less similar. The two Australian med-regions have 35% of similarity with the South African, California and Med-Basin communities, and 88% between them.

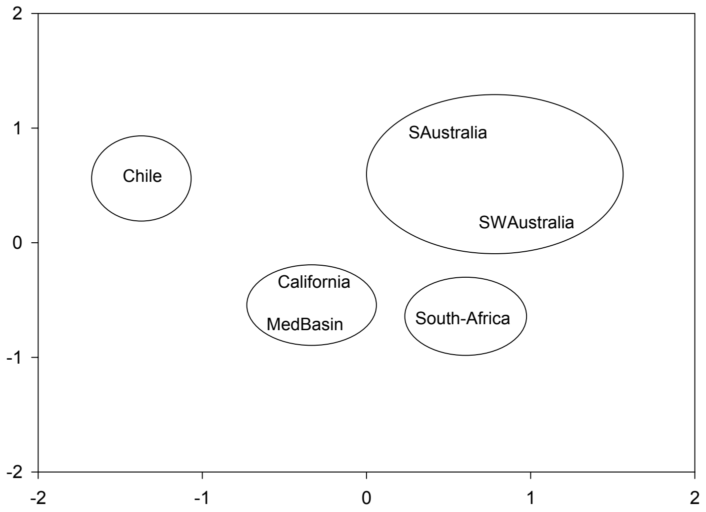


Figure 3. NMDS Plot using Jaccard distance.

The unique and common taxa are variable between regions (Table 2), being South Africa the region with a major number of unique taxa (13 families), followed by South Australia and Chile, both with 11 taxa. California and SWAustralia have few unique taxa, although some coldstenoterm plecopterans, as Peltoperlidae o Pteronarcyidae, are characteristic from North America. The med-region of SWAustralia has a scarce unique community, and only the caddisfly Plectotarsidae seems to be present in this area and absent in SAustralia. On the other hand, South Africa and Chile has important unique taxa from a Gondwanic origin, as Barbarochthonidae, Petrothrincidae and Hydrosalpingidae in South Africa and Austronemouridae or Diamphinoidae in Chile.

Table 2. Exclusive and ubiquitous taxa in the six med-regions.

Exclusive families

MEdBasin

Aphelocheiridae
Beraeidae
Bithynellidae
Ferrissiidae
Georrisidae
Limnebiidae
Neritidae
Polymitarcidae
Potamanthidae
Prosopistomatidae

California

Ameletidae
Peltoperlidae
Pteronarcyidae
Neiridae

Chile

Aeglidae
Amelotopsidae
Amnicolidae
Austronemouridae
Chilinidae
Coloburiscidae
Diamphipnoidae
Eomeropidae
Mesobdellidae
Molanidae
Samastacidae

SAustralia

Conoesucidae
Eusiridae
Hemicorduliidae
Nannochoristidae
Ochteridae
Paracalliopidae
Scatopsidae
Syllidae
Talitridae
Tasimiidae
Telephlebiidae

SWAustralia

Plectrotarsidae

SouthAfrica

Barbarochthonidae
Chlorophydae
Dipseudopsidae
Hydrosalpingidae
Munnidae
Petrothrincidae
Phreatoicidae
Pisuliidae
Potamonautidae
Protojaniridae
Spelaeogriphidae
Sternophysingidae
Teloganodidae

Ubiquitous families

Aeshnidae
Ancylidae
Baetidae
Caenidae
Ceratopogonidae
Chironomidae
Coenagrionidae
Corixidae
Culicidae
Dixidae
Dytiscidae
Elmidae
Empididae
Ephydridae
Gerridae
Gomphidae
Gordiidae
Gyrinidae
Haliplidae
Hydracarina
Hydrophilidae
Hydropsychidae
Hydroptilidae
Leptoceridae
Leptophlebiidae
Lestidae
Libellulidae
Lymnaeidae
Notonectidae
Oligochaeta
Physidae
Planorbidae
Polycentropodidae
Psychodidae
Simuliidae
Sphaeriidae
Stratiomyidae
Syrphidae
Tabanidae
Tipulidae

A total of 40 taxa are shared between all med-regions (Table 2), being dipterans the group with more common families. Ephemeroptera as Baetidae, Caenidae and Leptophlebiidae are also found in all med-regions, as well as the caddisflies Hydropsychidae, Hydroptilidae, Polycentropodidae and Leptoceridae, or other Coleoptera, Heteroptera and Odonata. On the other hand, many taxa are shared between several med-regions. For instance, because of their strong similarity, Med-Basin and California have 16 taxa in common (excluding the ubiquitous ones), as the stoneflies Nemouridae, Leuctridae, Capniidae, Chloroperlidae and Perlodidae, or the caddisfly Rhyacophilidae (absent in the southern hemisphere). Other taxa are present in all the med-regions except in one, as Pyralidae only absent in South Africa, Corduliidae or Ecnomidae in California, Glossosomatidae in SWAustralia or Athericidae, Dugesiidae and Hydraenidae in SAustralia. Moreover, this last continent lacks of families abundant in other regions as Blephariceridae, Dryopidae or Sericostomatidae (see Annex 1).

Crustaceans are the group more convergent between regions in southern hemisphere, with some variability. From the common taxa between SAustralia and SWAustralia, 5 are crustaceans (Ceinidae, Hymenosomatidae, Oniscidae, Parastacidae and Perthiidae), at the same time that Janiridae and Paramelitidae are shared with South Africa. This taxonomical group has numerous exclusive families in Southern Hemisphere (4 in SAustralia, 5 in South Africa and 2 in Chile). In northern hemisphere, there are few crustacean families, and only the Astacidae seems to be exclusive in Med-Basin and California. Other similarities in the crustacean taxa are between some taxa that has been introduced in several med-regions as Cambaridae from North America, introduced in Med-Basin and South Africa, or Grapsidae introduced in California and Med-Basin regions.

Another taxonomical group shared between med-regions in southern hemisphere is Odonata, with South Africa and SAustralia having 2 families in common (Chorolestidae and Protoneuridae), 1 between Chile and SWAustralia (Petaluridae), and 2 between both Australian med-regions (Synthemidae and Megapodagrionidae). Although there are a high similarity between Odonata and Crustacea in southern hemisphere, few convergences exist in other groups (excluding the ubiquitous taxa), as Ephemeroptera, with only the Onicigastridae shared by Chile and SAustralia. Plecoptera shows a typical distribution around med-regions, with more families in northern hemisphere (until 8) than in the South one: 4 in SAustralia, 7 in Chile, 1 in SWAustralia and 1 in South Africa. Notonemouridae is exclusive from South Africa, Chile and SAustralia, and absent in SWAustralia. In this last region, the Gripopterygidae are present and only shared with SAustralia and Chile. On the other hand, Chile and SAustralia have 2 common stoneflies (Austroperlidae and Eustheniidae) absent in other med-regions.

Many connections are found between north and southern hemisphere, as Noteridae or Platycnemidae in Med-Basin and South Africa, or Corylidae in South Africa, Chile and California. A relationship between northern hemisphere and South Africa or Chile is noticed, with some coldstenoterm families in fast flowing waters as Heptageniidae, Lepidostomatidae or Goeridae only in South Africa, California and Med-Basin; or as for example Perlidae, Psychomyiidae and Limnephilidae in the northern hemisphere and Chile. Other linkages between both Hemispheres are recent because the human introductions of Mollusca (Physidae in Australia, Hydrobiidae in Med-Basin, Corbiculiidae in California) or Crustacea (Cambaridae in Med-Basin and Grapsidae in California and Med-Basin).

When the list of taxa is analyzed for each med-region according to several multimetric indexes (Figure 4a-h), a differential composition among med-regions is found (Figure 4d-h). Communities from northern hemisphere have higher richness in Ephemeroptera, Plecoptera and Trichoptera, while in the southern hemisphere Coleoptera, Heteroptera, Diptera and non-Insect are more abundant. Taxa richness (as number of taxa) is slightly higher in Med-Basin (125), California (119), South Africa (104) and SAustralia (120), compare with Chile (92) and SWAustralia (98). However, even though this similarity in richness, taxonomical composition between med-regions is different (Figure 4b-h). Number of EPT appears to be high in Med-Basin, California, Chile and SAustralia (Figure 4b), because a major number of Plecoptera (Figure 4f), while is low on South Africa and SWAustralia with only one stonefly family (Notonemouridae and Gripopterygindae, respectively) (Annex 1). On the other hand, the low value of EPT/OCH in Australia would indicate that although having a high EPT value, the OCH are more important than in other med-regions (Figure 4h). In general, in southern hemisphere the percentage of non-insect taxa is higher, because of the presence of many crustacean families (Figure 4d). This phenomenon is more important in Australia and South Africa than in Chile, because in this last region the community is mainly composed by Ephemeroptera, Plecoptera and Trichoptera, being more similar to the northern hemisphere one at order level (Figure 4e-g).

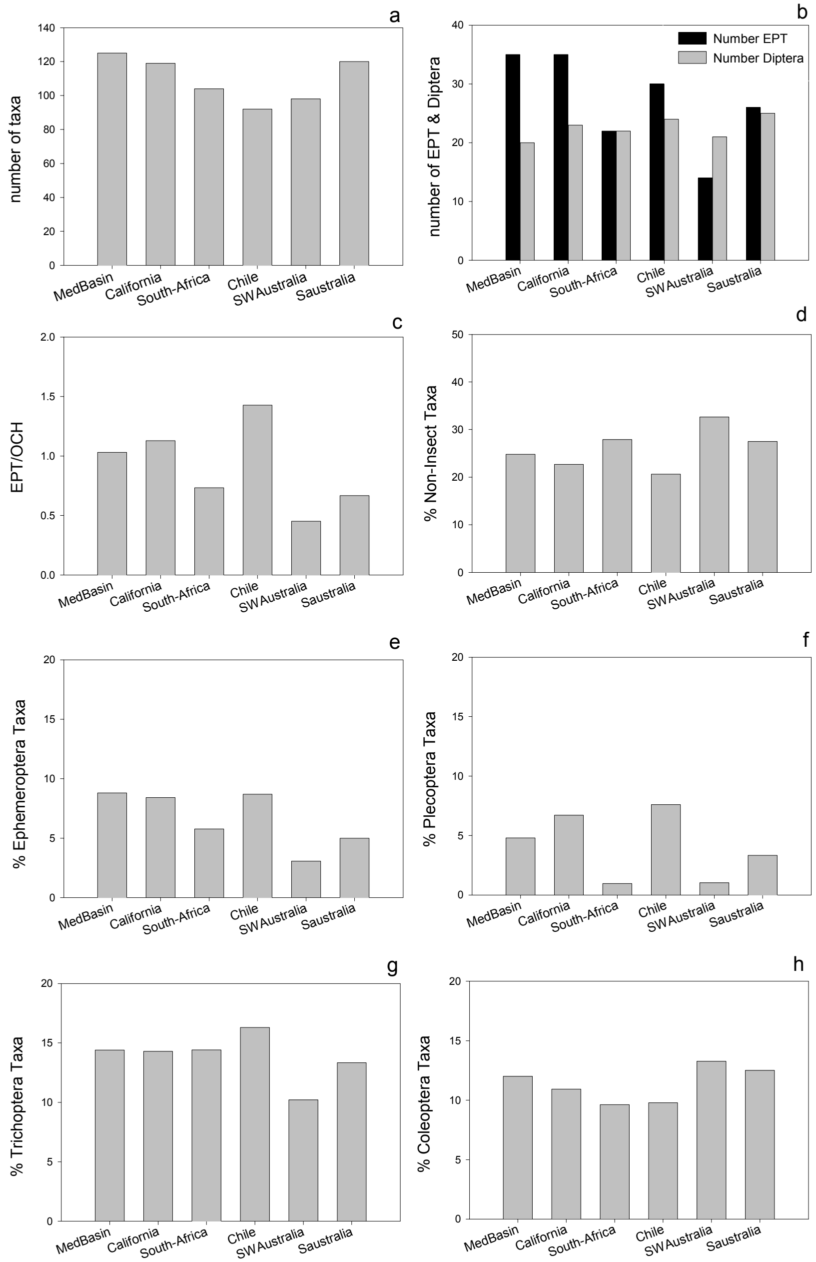


Figure 4. Multimetric indexes between mediterranean regions.

Differences between all sampling sites in med-regions

Physical, chemical and structural differences

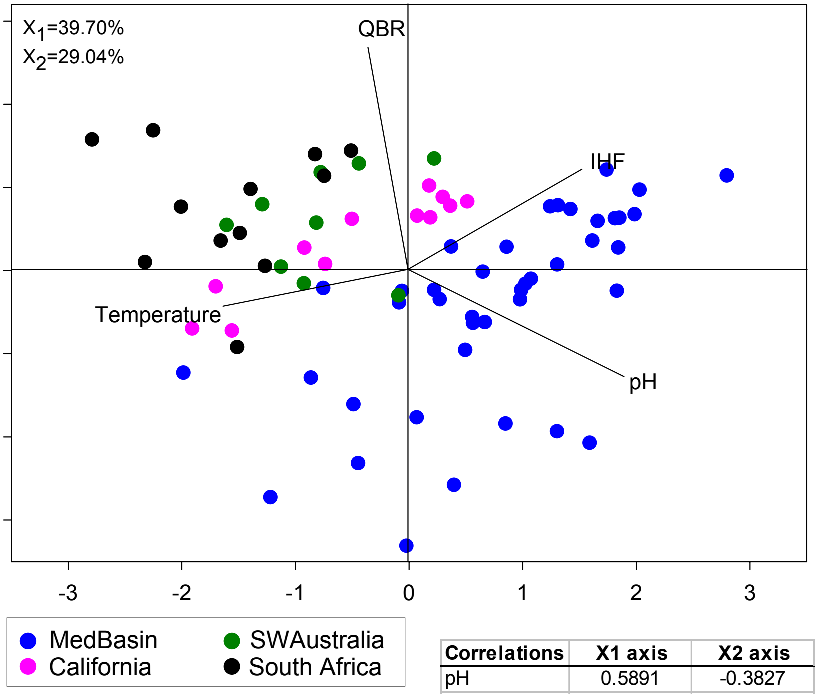
Pearson correlations between environmental variables, presented significant correlation between pH-Temperature (p=0.001), Temperature-Conductivity (p=0.034), Temperature-Discharge (p=0.03), Temperature-IHF (p=0.008) and QBR-Conductivity (p=0.002) (Table 3). Because the correlation coefficients were low (r<0.4) all variables were used in further analysis. Skewness values associated to each variable showed that Conductivity (s=7.449) and Discharge (s=7.569) had a high data asymmetry and consequently were deleted from the PCA analysis (Table 3). Only QBR, pH, temperature and IHF were used to avoid a bias in the results.

Table 3. Pearson correlations and skewness values for all measured environmental features. In bold, significant correlations (p<0.05) and high skewness values. Temp: temperature; Cond: conductivity; Dis: discharge.

		pH	**Temp**	**Cond**	**QBR**	**IHF**	**Dis**	**Skewness**
pH	*r-Pearson*		**-0.379**	0.137	-0.226	0.183	-0.133	
	p-value		0.001	0.245	0.053	0.118	0.260	-1.310
Temp	*r-Pearson*	**-0.379**		**0.246**	-0.067	**-0.305**	**0.252**	
	p-value	0.001		0.034	0.571	0.008	0.030	0.004
Cond	*r-Pearson*	0.137	**0.246**		**-0.359**	-0.146	-0.069	
	p-value	0.245	0.034		0.002	0.214	0.561	**7.449**
QBR	*r-Pearson*	-0.226	-0.067	**-0.359**		0.101	0.122	
	p-value	0.053	0.571	0.002		0.391	0.299	-1.854
IHF	*r-Pearson*	0.183	**-0.305**	-0.146	0.101		-0.114	
	p-value	0.118	0.008	0.214	0.391		0.335	-0.249
Dis	*r-Pearson*	-0.133	**0.252**	-0.069	0.122	-0.114		
	p-value	0.260	0.030	0.561	0.299	0.335		**7.569**

The first two PCA axis from the analysis made with selected variables explain 68.74% of total variability of the physical-chemical data and results are plotted in Figure 5. First axis is highly correlated positively with pH (r=0.5891) and IHF (r=0.4995) and negatively with temperature (r=-0.6315), whereas QBR is located positively and near the second axis (r=0.8313). Thereby, X_2-axis would be related to a good riparian status, and the X_1-axis with abiotic factors as pH, temperature and habitat diversity availability. A clear segregation of sites is noticed between med-regions, and different physical-chemical conditions can be associated with each one.

Reference sites in Med-Basin have a higher pH and IHF compare with SWAustralia and South Africa, but a lower riparian quality. Californian sites are located near Med-Basin with more neutral pH but variable conditions of riparian vegetation and habitat diversity. Finally, samples from South Africa and SWAustralia are associated with low pH, high temperature, good riparian quality and medium to lower habitat diversity.



Correlations	X1 axis	X2 axis
pH	0.5891	-0.3827
Temperature	-0.6315	-0.1518
QBR	-0.0686	0.8313
IHF	0.4995	0.3735

Figure 5. PCA plot with environmental variables in reference sites.

Relative abundance of common taxa between sampled med-regions

In Table 4, results of the non-parametric ANOVA (model Kruskal-Wallis by ranks) indicate that in permanent sites, the relative abundance of taxa is variable between med-regions, with a 51% of common taxa showing significative differences in abundance between regions (p-value<0.05 in Table 4). The rest of taxa have a similar abundance between regions, including the abundants Caenidae, Hydropsychidae, Hydroptilidae, Ostracoda, Corixidae, several Odonata and several infrequent taxa (Thyaridae, Sphaeriidae, Sciomyzidae, Dolichopodidae…).

Table 4. Kruskal-Wallis non-parametric tests with relative abundances of common taxa in MedBasin, California, South Africa and SWAustralia permanent sites. *p<0.05 and **p<0.001.

	Chi-squared (K-W test)	**p-value**	
Aeshnidae	12.46	0.006	**
Ancylidae	8.4	0.038	*
Anthomyidae	1.58	0.662	
Athericidae	11.4	0.009	**
Atyidae	8.15	0.043	*
Baetidae	11.79	0.008	**
Caenidae	3.5	0.32	
Ceratopogonidae	14.5	0.002	**
Chironomidae	16.12	0.001	**
Coenagrionidae	8.43	0.037	*
Corixidae	1.05	0.787	
Culicidae	0.7	0.873	
Dixidae	12.25	0.006	**
Dolichopodidae	2.18	0.535	
Dugesiidae	4.16	0.244	
Dytiscidae	6.79	0.078	
Elmidae	11.12	0.011	*
Empididae	15.79	0.001	**
Ephidridae	0	1	
Gerridae	17.36	0	**
Gomphidae	4.46	0.215	
Gyrinidae	4.04	0.256	
Haliplidae	6.22	0.101	
Helodidae	14.16	0.002	**
Hydracarina	11.44	0.009	**
Hydraenidae	20.19	0	**
Hydrobiidae	9.25	0.026	*
Hydrometridae	2.18	0.535	
Hydrophilidae	2.02	0.567	
Hydropsychidae	1.66	0.644	
Hydroptilidae	0.62	0.89	
Leptoceridae	23.62	0	**

Leptophlebiidae	17.11	0	**
Lestidae	2.3	0.511	
Libellulidae	1.6	0.658	
Lymnaeidae	7.42	0.059	
Naucoridae	2.18	0.535	
Nepidae	6.4	0.091	
Notonectidae	9.49	0.023	*
Oligochaeta	15.16	0.001	**
Ostracoda	6	0.111	
Philopotamidae	11.58	0.009	**
Physidae	10.41	0.015	*
Planorbidae	5.71	0.126	
Pleidae	2.18	0.535	
Polycentropodidae	8.43	0.037	*
Psychodidae	1.64	0.648	
Sciomyzidae	0	1	
Simuliidae	19	0	**
Sphaeriidae	5.96	0.113	
Stratiomyidae	9.25	0.026	*
Tabanidae	8.43	0.037	*
Thyaridae	1.56	0.459	
Tipulidae	13.79	0.003	**
Veliidae	11.89	0.007	**

Figure 6 plot the average of relative abundance patterns for all significant taxa ($p<0.005$) between sampled med-regions permanent sites. Oligochaeta, Baetidae, Chironomidae and Simuliidae are very abundant in all med-regions although several differences and similarities are present between them. For most groups of taxa, greater differences in the abundance pattern are shown in the interhemispheric comparisons, whereas the intrahemispheric show higher similarities (Figure 6). The sampled area in Med-Basin is characterized by a higher number of Mollusca, Coleoptera, Chironomidae, Notonectidae and Baetidae, but a lower Leptophlebiidae, Hydracarina and Simuliidae compared with California (Figure 6). Fewer similarities in relative abundance are shown between South Africa and SWAustralia with higher numbers of Leptoceridae in contrast to MedBasin and California.

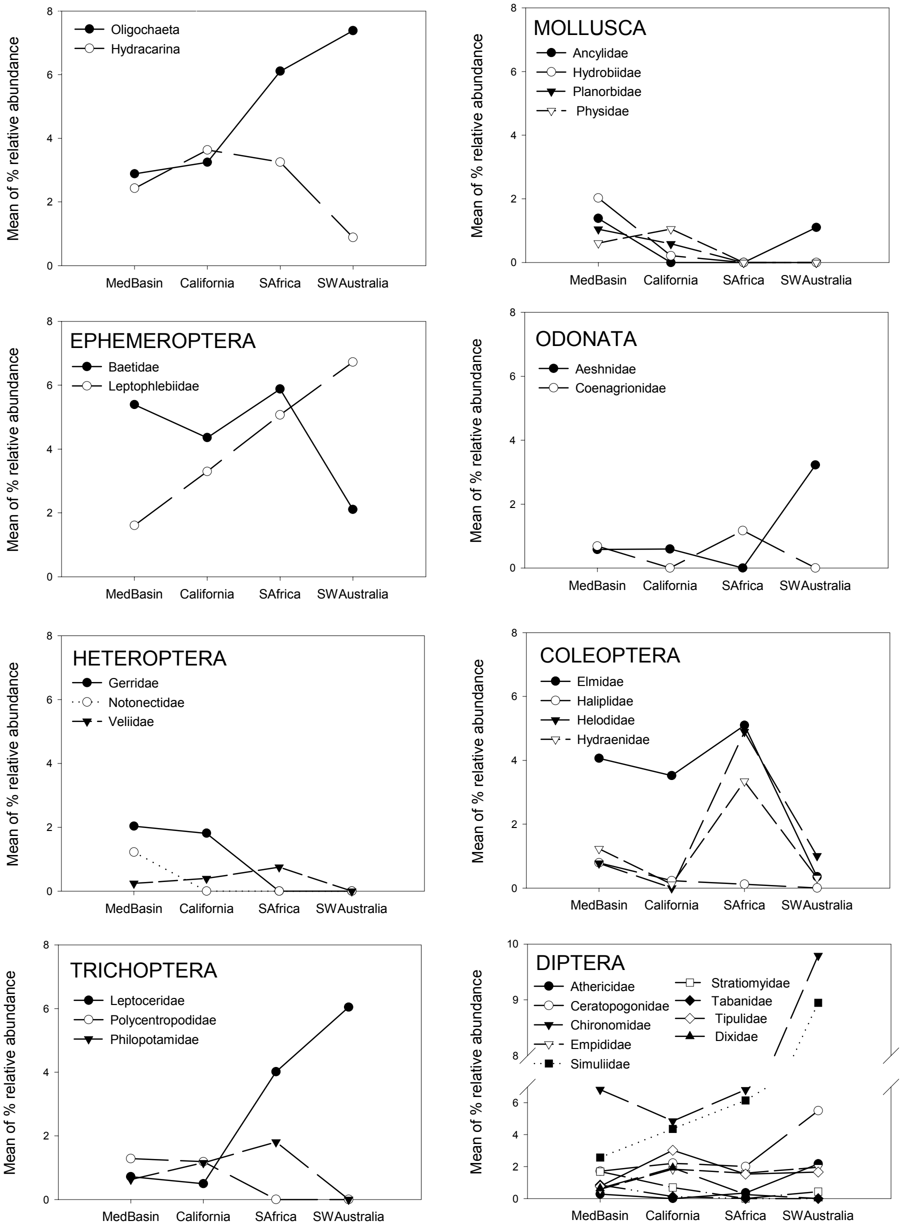


Figure 6. Mean of the abundances relatives for permanent sampled sites in MedBasin, California, South Africa and SWAustralia. Only the significant taxa are plotted (p<0.005).

However, southern hemisphere med-regions present lower abundances of Mollusca, Heteroptera, Polycentropodidae and some Diptera compared with northern hemisphere. South Africa is characterized by a high relative abundance of Elmidae, Helodidae and Hydraenidae compared with the other med-regions, but a low abundance in Mollusca. In SWAustralia, Oligochaeta, Aeshnidae, Leptophlebiidae, Chironomidae, Simuliidae and Ceratopogonidae are more abundant than other med-regions. Consequently, other taxa are less frequent as Coleoptera, Heteroptera, Hydracarina, Polycentropodidae, Philopotamidae and Baetidae (Figure 6).

Effect of temporality

Although similarities and differences between some med-regions were shown by common taxa abundances for permanent sites, responses of communties to temporality may also differ between areas. Results from Bray-Curtis Cluster made with common taxa in all med-regions (Figure 7), indicate differences between regions are higher than between permanent and temporary sites. Each region is grouped together, and in each cluster permanent and temporary sites are included. MedBasin is the first region to be clustered, followed by SWAustralia. California and South Africa appear closer, indicating a similar response of communities to temporality. However, when each region is analysed independent of the other, and all taxa (common and exclusive) are analysed, differences in macroinvertebrate community between permanent and temporary sites ($p<0.01$) are found in all regions except for SWAustralia ($p>0.05$), as is show in Table 5.

Table 5. MRPP results between different categories and regions. *p<0.05 and **p<0.001.

	PERMANENT vs TEMPORAL		**RIFFLES vs POOLS**	
	A	p-value	A	p-value
Med-Basin	0.036	0.0000014**	0.03	0.017*
California	0.0664	0.0084**	0.1182	0**
SouthAfrica	0.0666	0.0094**	0.0839	0**
SWAustralia	0.011	0.3192	0.0789	0**

The macroinvertebrate assemblage in SWAustralia and South Africa has a number of taxa, dipterans, EPT/OCH similar between permanent and temporary sites (Figure 8 and Table 6).

For the rest of med-regions number of taxa and % of non-insect taxa is similar between permanent and temporary sites, but there are differences in the EPT/OCH ratio and the number of dipterans. MedBasin has a significantly higher EPT/OCH in permanent sites than temporary, whereas in California, even though this ratio is also higher in permanent localities, it is not significant. Number of dipterans is significantly lower in permanent sites from California, but similar to temporary in the rest of sampling areas.

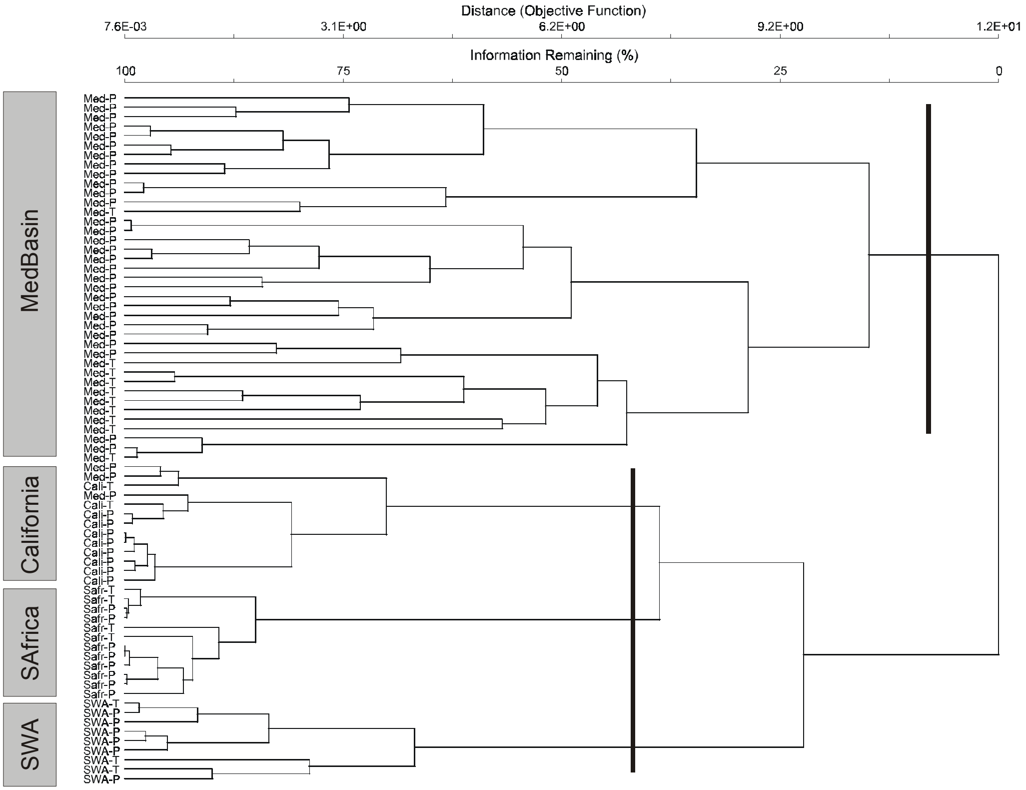


Figure 7. Bray-Curtis cluster with common matrix and permanent and temporary reference sites.

When the analysis are performed comparing all regions separately in permanent and temporary sites (Table 6), only number of taxa and EPT/OCH ratio in permanent sites are significantly different between med-regions. For both metrics, California has higher values in permanent sites compared with the rest of med-regions. No differences exist between regions for all metrics in temporary sites, although box-plot graphs indicate lower higher number of taxa and dipterans in California but a low % of non-insect taxa respect the other regions.

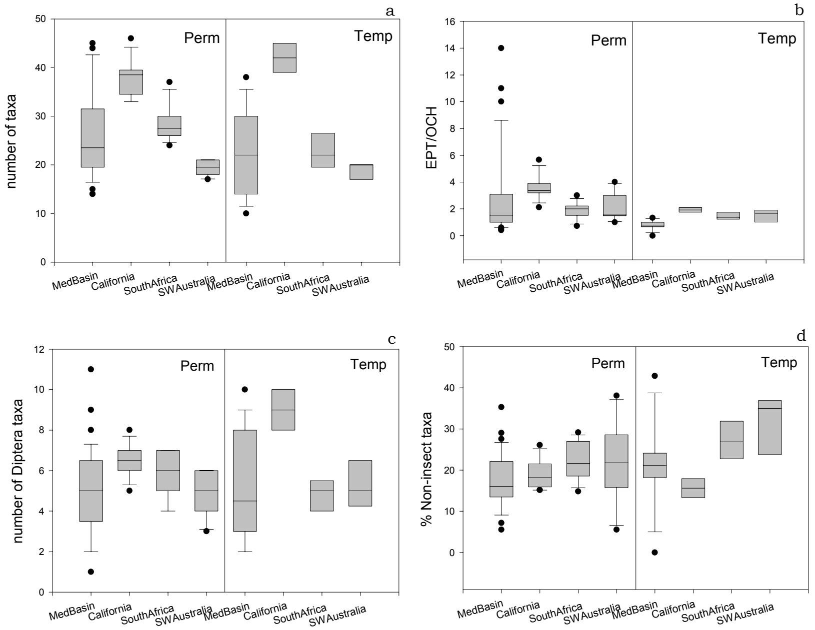


Figure 8. Box-plot between permanent and temporary reference sites.

Table 6. Kruskal-Wallis non-parametric tests between med-regions and temporality. PERM=permanent sites and TEMP=temporary sites. * p<0.05 and **p<0.001.

		Taxa	EPT/OCH	Dipterans	%Non-insect
PERM among regions	*Chi-squared K-W test*	15.52	9.7916	4.7769	3.666
	p-value	**0.0014****	**0.0204***	0.1889	0.2998
TEMP among regions	*Chi-squared K-W test*	4.96	6.899	0.3886	3.6909
	p-value	0.1747	0.0752	0.274	0.2968
MedBasin	*Chi-squared K-W test*	0	4.72	0.364	2.1
	p-value	1	**0.0297***	0.5459	0.1473
California	*Chi-squared K-W test*	0.4761	2.5	5.833	1.666
	p-value	0.4902	0.1139	**0.0157***	0.1967
South Africa	*Chi-squared K-W test*	1.5	0.6857	2	1.5
	p-value	0.2207	0.4076	0.1573	0.2207
SW Australia	*Chi-squared K-W test*	1.2857	0.9	0	0.9
	p-value	0.2568	0.3428	1	0.3428

The values of IV-values for each taxon obtained with IndVal analysis are shown in Table 7. Firstly, it is interesting to note, that although no significant differences are found between permanent and temporary sites in SWAustralia (Table 5), several taxa appear to have a high IV-value. Overall, the general pattern observed indicates that in springtime, permanent community present more taxa characteristic from riffles, whereas temporary sites have a pool of more tolerant taxa. Thereby, EPT taxa are more common in permanent localities and OCH in temporary ones. Several convergences are observed among regions, with MedBasin and California sharing taxa as Rhyacophilidae, Perlidae and Ephemerellidae in permanent sites. Other plecopterans as Nemouridae have a high IV-value in temporary sites in MedBasin, but in permanent localities in California. The SWAustralia stonefly Gripopterygidae and Notonemouridae in South Africa have a high IV-value in temporary sites. Ephemeroptera are also more common in permanent sites than in temporary ones with Ephemerellidae in MedBasin and California and Teloganodidae in South Africa, or Heptageniidae in MedBasin and South Africa. On the other hand, Leptophlebiidae only is a family associated to permanent localities in SWAustralia whereas is more typical from temporary sites in MedBasin and South Africa. Some caddisflies are also more abundant in permanent than in temporary sites as the reophilic families Hydropsychidae (MedBasin, South Africa and SWAustralia) or Rhyacophilidae (MedBasin and California) or the close family Hydrobiosidae (SWAustralia) or its equivalent in South Africa (the predator Corydalidae). Hydroptilidae and the mayfly Caenidae are permanent families in MedBasin and SWAustralia but associated to temporary habitats in California. Other caddis exclusive form South Africa have found in permanent sites as the lotic families Barbarocthonidae and Petrothrincidae, whereas Pisuliidae is indicator of temporary localities. Leptoceridae, a very abundant caddisfly in southern hemisphere, is characteristic from permanent sites there, but from temporary reaches in California. Similar pattern is observed in Hydropsychidae, Elmidae and Heptageniidae, characteristic from permanent sites in MedBasin and South Africa but from more temporary sites in California.

Table 7. IndVal results between permanent and temporary sites for each med-region. Line separates taxa significant at p<0.05 from not significant. Non-significant taxa are from high indicator values (IV) to low. Only taxa with IV higher than 25 are presented (Dûfrene & Legendre, 1997).

MEDBASIN

Permanent	*IV*	*p-value*	**Temporary**	*IV*	*p-value*
Elmidae	65	0	Hydrometridae	72.5	0
Baetidae	69	0	Veliidae	41.4	0
Hydropsychidae	70	0	Hydrophilidae	38.1	0.03
Heptageniidae	56	0.02	Planorbidae	33.1	0.04
Gomphidae	44	0.02	Culicidae	28.2	0.04
Perlidae	49	0.02	Dytiscidae	54.1	0.05
Calopterygidae	38	0.04	Chironomidae	52.9	0.26
Hydroptilidae	48	0.05	Ostracoda	42.2	0.09
Simuliidae	49	0.07	Oligochaeta	41.8	0.43
Rhyacophilidae	48	0.07	Gerridae	37.8	0.21
Ephemerellidae	39	0.15	Stratiomyidae	34.7	0.29
Caenidae	39	0.18	Leptophlebiidae	33.8	0.12
Hydracarina	38	0.54	Notonectidae	33.2	0.17
Hydrobiidae	35	0.11	Ceratopogonidae	32	0.79
Gammaridae	34	0.13	Hydraenidae	31.4	0.23
Helodidae	31	0.09	Lymnaeidae	30.5	0.18
Limnephilidae	30	0.97	Nemouridae	29.9	0.45
Brachycentridae	28	0.13			
Ephemeridae	25	0.16			

CALIFORNIA

Permanent	*IV*	*p-value*	**Temporary**	*IV*	*p-value*
Ceratopogonidae	81	0.029	Culicidae	100	0.029
Limnephilidae	100	0.029	Stratiomyidae	95.2	0.053
Perlidae	85.7	0.029	Caenidae	88.9	0.073
Rhyacophilidae	85.2	0.029	Corixidae	85.7	0.074
Nemouridae	85.7	0.055	Brachycentridae	80	0.078
Ephemerellidae	84.6	0.058	Physidae	76.2	0.108
Nematoda	75	0.138	Hydroptilidae	75.7	0.053
Sialidae	75	0.164	Philopotamidae	63.2	0.202
Tipulidae	64.7	0.071	Oligochaeta	58.3	0.35
Empididae	61.9	0.286	Dixidae	57.1	0.589
Dytiscidae	52.5	0.629	Chloroperlidae	57.1	0.618
Calamoceratidae	50	0.453	Ostracoda	55.8	0.683
Sphaeridae	50	0.457	Hydracarina	54.9	0.352
Peltoperlidae	50	0.475	Lepidostomatidae	54.1	0.58
Asellidae	37.5	0.55	Hydropsychidae	52.2	1
Cordulegasteridae	37.5	0.681	Heptageniidae	51.3	0.933
Perlodidae	37.5	0.705	Elmidae	51.1	1
Odontoceridae	37.5	0.709	Belostomatidae	50	0.2
Psephenidae	37.5	0.912	Ephydridae	50	0.2
Glossosomatidae	28.4	1	Haliplidae	50	0.2
Psychodidae	27.8	1	Sciomyzidae	50	0.2
Corydalidae	25	1	Coenagrionidae	50	0.212
	25	1	Hydraenidae	50	0.212
			Naucoridae	50	0.212
			Tabanidae	50	0.212
			Polycentropodidae	50	0.465
			Chironomidae	50	1
			Gerridae	50	1
			Psychomyiidae	44.4	0.2
			Hydrophilidae	40	0.222
			Tricorytidae	40	0.238
			Lestidae	40	0.377
			Gomphidae	36.4	0.601
			Planorbidae	36.4	0.602
			Dugesiidae	35.3	0.593
			Sericostomatidae	35.3	0.729
			Siphlonuriidae	33.3	0.381
			Pteronarcydae	33.3	0.381
			Leptoceridae	33.3	1
			Oribatidae	28.6	1
			Uenoidae	28.6	1
			Aeshnidae	28.6	1
			Cambaridae	25	1
			Helicopsychidae	25	1

SOUTH AFRICA

Permanent	*IV*	*p-value*	**Temporary**	*IV*	*p-value*
Barbarocthonidae	88	0.01	Paramelitidae	86.7	0.01
Leptoceridae	71	0.02	Hydracarina	56.2	0.46
Hydropsychidae	67	0.08	Nematoda	51.9	0.81
Blephariceridae	66	0.11	Oligochaeta	51.7	0.58
Petrothrincidae	63	0.12	Leptophlebiidae	51.1	1
Elmidae	57	0.06	Chironomidae	50	1
Teloganodidae	57	0.18	Notonemouridae	47.8	1
Baetidae	56	0.17	Helodidae	47.8	1
Hydraenidae	56	0.56	Dytiscidae	42.9	0.17
Simuliidae	54	0.07	Ostracoda	37.5	1
Glossosomatidae	53	0.31	Dugesiidae	30.8	0.85
Tipulidae	52	0.37	Hirudinidae	25	0.32
Coenagrionidae	50	0.19	Pisuliidae	25	0.34

SWAUSTRALIA

Permanent	*IV*	*p-value*	**Temporary**	*IV*	*p-value*
Hydropsychidae	68.4	0.13	Griptopterygidae	61.5	0.25
Baetidae	66.7	0.172	Hydracarina	53.3	0.235
Leptophlebiidae	61.5	0.23	Oligochaeta	51.6	1
Simuliidae	55.6	0.358	Chironomidae	50	1
Aeshnidae	55.6	0.48	Perthiidae	44.4	0.393
Ceratopogonidae	54.5	0.635	Psychodidae	44.4	0.48
Leptoceridae	52	1	Dytiscidae	44.4	0.523
Corduliidae	50	0.371	Ostracoda	44.4	0.643
Athericidae	50	0.387	Tipulidae	38.1	0.519
Hydroptilidae	50	0.396	Coenagrionidae	33.3	0.305
Hydrobiosidae	50	0.412	Gyrinidae	33.3	0.325
Empididae	47.6	0.461	Stratiomyidae	33.3	0.325
Parastacidae	44.4	0.543	Nematoda	29.6	1

Temporary sites are characterized by high abundance of OCH taxa, together with some other taxa as Mollusca, Oligochaeta and Crustacea. Dytiscidae is a temporary family in MedBasin, South Africa and SWAustralia but not in California, whereas Haliplidae only have a high IV-value in temporary sites of California. On the other hand, Gyrinidae is an indicator family only of SWAustralia and MedBasin. Heteroptera are exclusively temporary families, but Odonata have permanent and temporary taxa. Lestidae, Gomphidae and Coenagrionidae are temporary families in California. Coenagrionidae also is a temporary family in SWAustralia but a permanent in South Africa. Similar divergences are observed with Gomphidae, a significant Odonata family found in permanent sites in MedBasin but with a high IV-value in temporary sites of California. Crustaceans and Mollusca appear to be more indicator taxa from temporary than permanent sites, with Planorbidae present in MedBasin and California, or Lymnaeidae common in MedBasin and Physidae in California. Other taxa are present in temporary sites in all med-regions, as Ostracoda or Oligochaeta.

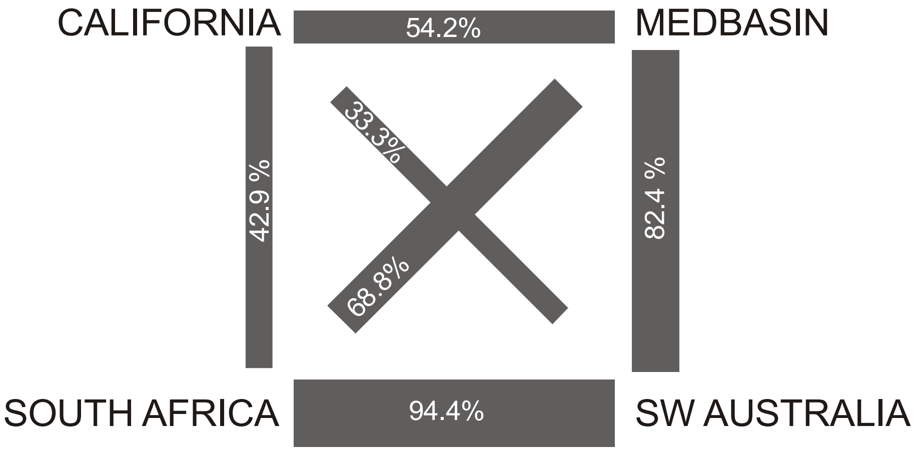


Figure 9. Percentages of similarity between med-regions considering common abundant and representative (IV-value) taxa for each pair of med-regions, in permanent and temporary sites.

Figure 9 displays percentages of similarities in macroinvertebrate responses under permanency and temporality between each pair of med-regions. These similarity values were obtained using common taxa with high IV-values (very abundant and representative) present between pair of med-regions. When comparing two med-regions if a common family was representative from different conditions (permanent or temporary) in one region respect to the others, it was recorded as a disimilarity, whereas when a family display a similar affinity in both regions it was recorded as a similarity. Thereby, and according to Figure 9, the highest percentage of similarity is shown between South Africa and SWAustralia, indicating that common taxa with high indicator values display a similar pattern in both regions. Consequently, 94.4% of the common and abundant taxa between South Africa and SWAustralia present a similar response to the permanency and temporality. On the other hand, MedBasin and SWAustralia also show a high similarity, compared with the rest of paired-comparisons. In fact, California and MedBasin, even though sharing more families with a high IV-value than the other regions only 54.2% of the taxa display a similar segregation in permanent and temporary sites.

Habitat effects

In Figure 10 the cluster using all common taxa in sampled med-regions is presented. Differences between regions are higher than between habitats in South Africa and SWAustralia

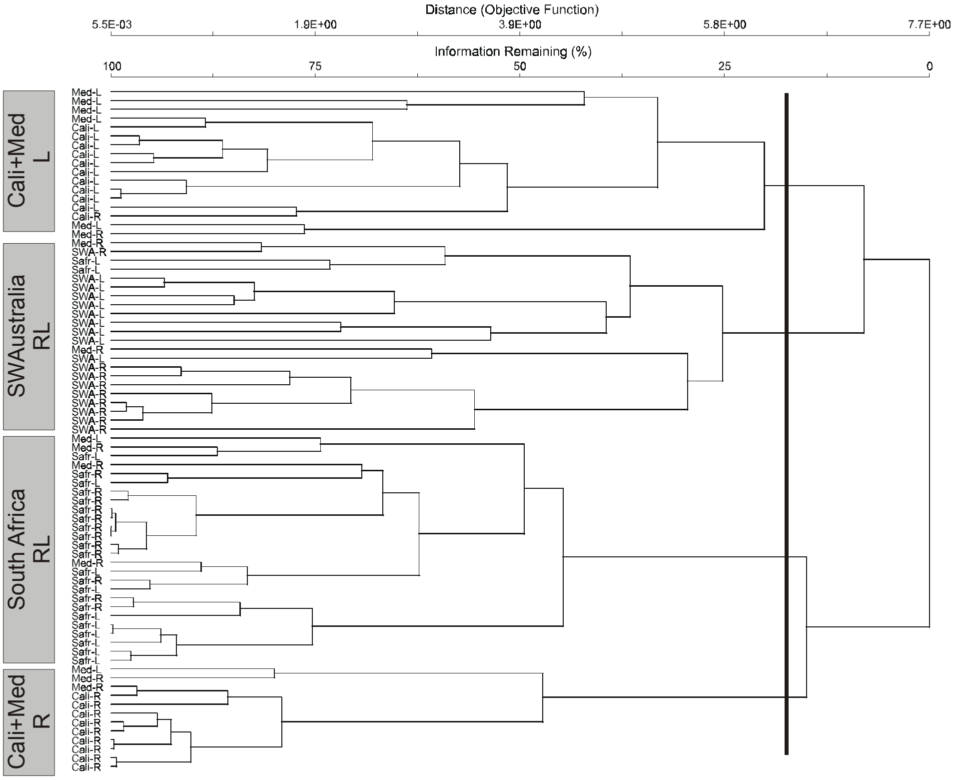


Figure 10. Bray-Curtis cluster with common matrix and riffles and pools reference sites.

but not for MedBasin and California. In northern hemisphere med-regions, common taxa have a similar composition and abundance in each habitat independently of the region, especially in pools. Riffles in MedBasin, although they are closer to the Californian ones, have a higher variability in composition and abundance and are closer to SWAustralia and South Africa than to lentic habitats of Med-Basin and California. However, for each region independently and all taxa, MRPP results (Table 5) show that in studied sites all med-regions have significant differences between the macroinvertebrate assemblage of riffles and pools. Number of taxa is similar between R and L in all regions (Figure 11 and Table 8), but some differences are found with the rest of metrics. EPT/OCH ratio is significant higher in R than L in all med-regions except for South Africa (p>0.005) (Table 8). SWAustralia and South Africa have a significant higher number of dipterans in R compared with MedBasin and California. Percentage of non-insect taxa only displays significant differences among habitats in South Africa where a lower number of non-insect taxa are observed in R than L.

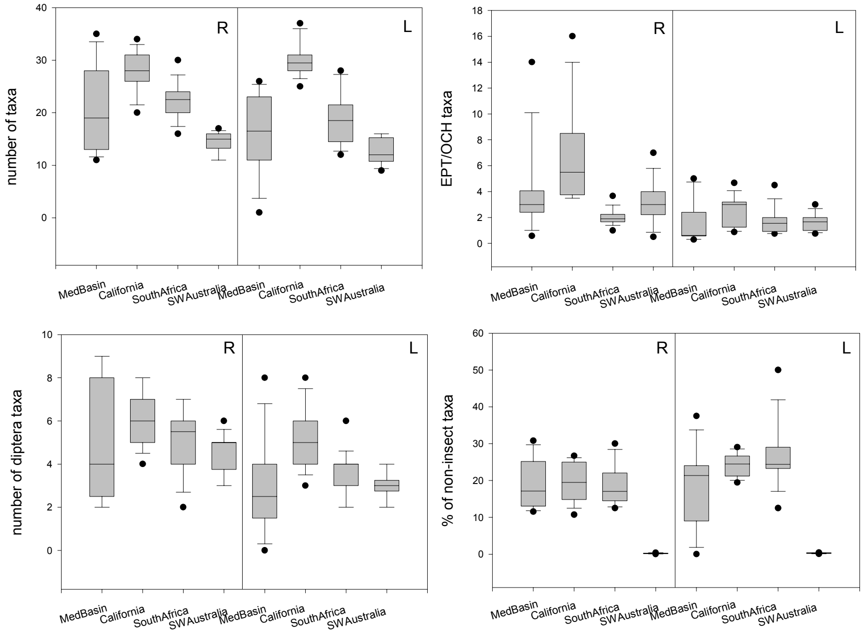


Figure 11. Box-Plot between riffles and pools for reference sites.

Table 8. Kruskal-Wallis non-parametric tests between med-regions and habitat. R=riffles and L=pools. * p<0.05 and **p<0.001.

		Taxa	**EPT/OCH**	**Dipterans**	**%Non-insect**
R among regions	*Chi-squared K-W test*	15.76	19.51	5.25	11.91
	p-value	**0.0013****	**0.0002****	0.1539	**0.0077****
L among regions	*Chi-squared K-W test*	19.48	2.6	17.07	15.46
	p-value	**0.0002****	0.4575	**0.0007****	**0.0015****
MedBasin	*Chi-squared K-W test*	0	4.666	1	0.253
	p-value	1	**0.0308***	0.3173	0.6143
California	*Chi-squared K-W test*	0.202	9.8989	1.8181	3.2
	p-value	0.6531	**0.0017****	0.1775	0.0736
South Africa	*Chi-squared K-W test*	2.7428	2.666	8.7111	6
	p-value	0.0977	0.1025	**0.0032****	**0.0143***
SW Australia	*Chi-squared K-W test*	0.9	7.244	5.555	2
	p-value	0.3428	**0.0071****	**0.0184***	0.1573

When habitats are considered separately, several differences between med-regions are found in all metrics. Thus, California has a higher number of taxa in R and L separately, a higher EPT/OCH ratio in riffles and a higher number of dipterans in L, compared with the rest of med-regions. Significant differences found in the percentage of non-insect fauna are because of the lower values found in SWAustralia in both habitats separately, in contrast with the observed in the rest of sampled areas (Table 8).

Convergences and divergences between habitats in med-regions are given in detail in Table 9, where IndVal results are presented. The significant families and the ones with a high IV-value but non-significant have to be understood in terms of presence and relative abundance of each taxa in each region. Hydropsychidae and Simuliidae are significantly abundant in riffles in all med-regions, whereas other taxa are exclusive from one, two or three regions. All the plecopterans found in MedBasin and California and the respective families found in southern hemisphere (Notonemouridae and Gripopterygidae) have higher IV-value in riffles than in pools. Within the Ephemeropterans, Ephemerellidae is typical from riffles in California and MedBasin, and the close family Teloganodidae is in South Africa. Heptageniidae is a common family found in riffles in MedBasin and California, but without habitat preferences in South Africa and absent in SWAustralia. Differences in habitat preferences are found in

Table 9. IndVal results between riffles and pool habitats for each med-region. Line separates taxa significant at p<0.05 from not significant. Non-significant taxa are from high indicator values (IV) to low. Only taxa with IV higher than 25 are presented (Dūfrene & Legendre, 1997).

MEDBASIN

Riffles	*IV*	*p-value*	**Pools**	*IV*	*p-value*
Hydropsychidae	63	0.03	Gerridae	87.5	0
Simuliidae	63	0.03	Dytiscid	62.5	0.02
Ephemerellidae	60	0.07	Hydrometridae	45.5	0.21
Ceratopogonidae	55	0.21	Culicidae	37.5	0.2
Chironomidae	54	0.56	Hydrophilidae	37.5	0.2
Nemouridae	51	0.12	Coenagrionidae	37.5	0.21
Elmidae	51	0.11	Hydracarina	37.5	1
Chloroperlidae	50	0.08	Leptophlebiidae	33.7	0.89
Erpobdellidae	50	0.08	Polycentropodidae	27.3	0.6
Hydroptilidae	50	0.08	Nepidae	25	0.46
Perlodidae	50	0.09	Notonectidae	25	0.47
Limnephilidae	49	0.5	Hydrobiidae	25	0.47
Perlidae	44	0.12			
Betidae	43	0.61			
Heptageniidae	42	0.33			
Oligochaeta	40	0.8			
Tabanidae	38	0.2			
Leuctridae	38	0.2			
Hydraenidae	33	0.34			
Sericostomatidae	31	0.33			
Ostracoda	29	0.77			
Caenidae	29	0.8			
Empididae	30	0.43			
Rhyacophilidae	27	0.54			
Glossosomatidae	25	0.47			
Limoniidae	25	0.47			

CALIFORNIA

Riffles	*IV*	*p-value*	**Pools**	*IV*	*p-value*
Hydropsychidae	93.3	0.001	Gerridae	84.4	0.002
Simuliidae	87.8	0.001	Dytiscidae	74.1	0.005
Tipulidae	73.5	0.005	Sialidae	60	0.007
Rhyacophilidae	72	0.008	Leptophlebiidae	64.3	0.027
Perlidae	68.2	0.016	Ceratopogonidae	60	0.077
Baetidae	56.2	0.017	Ostracoda	58.4	0.068
Chloroperlidae	66.7	0.031	Lepidostomatidae	56.8	0.07
Heptageniidae	60	0.085	Chironomidae	50	1
Ephemerellidae	58.2	0.139	Limnephilidae	46.2	0.296
Oligochaeta	57.4	0.188	Calamoceratidae	40	0.09
Elmidae	55.8	0.187	Gomphidae	40	0.106
Nemouridae	53.6	0.269	Oribatidae	40	0.121
Hydracarina	51.9	0.744	Sericostomatidae	35.6	0.179
Empididae	48.7	0.516	Physidae	34.3	0.555
Philopotamidae	45.5	0.07	Corixidae	33.3	0.228
Polycentropodidae	43.6	0.064	Sphaeridae	32	0.299
Hydroptilidae	42	0.43	Nematoda	31.2	0.646
Glossosomatidae	36.7	0.443	Cordulegasteridae	30	0.204
Psephenidae	35	0.707	Aeshnidae	30	0.232
Peltoperlidae	34.3	0.247	Dixidae	30	0.998
Dugesiidae	32	0.225			
Uenoidae	31.1	0.341			
Brachycentridae	26.7	0.522			

SOUTH AFRICA

Riffles	*IV*	*p-value*	**Pools**	*IV*	*p-value*
Simuliidae	78	0	Ostracoda	55.3	0.06
Hydraenidae	74	0	Oligochaeta	53.8	0.23
Philopotamidae	67	0	Nematoda	44.9	0.66
Teloganodidae	62	0.01	Ceratopogonidae	39.7	0.68
Notonemouridae	67	0.01	Ecnomidae	30	0.64
Blepharoceridae	55	0.01	Coenagrionidae	28.6	0.22
Hydropsychidae	53	0.02			
Leptophlebiidae	63	0.02			
Baetidae	58	0.08			
Elmidae	57	0.11			
Helodidae	55	0.17			
Chironomidae	52	0.15			
Hydracarina	51	0.53			
Empididae	49	0.15			
Tipulidae	48	0.06			
Leptoceridae	44	0.81			
Glossosomatidae	38	0.12			
Corydalidae	33	0.1			
Potamonantidae	25	0.21			

SWAUSTRALIA

Riffles	*IV*	*p-value*	**Pools**	*IV*	*p-value*
Simuliidae	90.3	0.001	Leptoceridae	59.3	0.146
Hydropsychidae	88.9	0.001	Ostracoda	47.6	0.122
Ceratopogonidae	62.5	0.08	Dytiscidae	35.6	0.279
Griptopterygidae	60.4	0.12	Corduliidae	35.4	0.557
Oligochaeta	60.3	0.134	Gomphidae	29.6	0.621
Leptophlebiidae	54.5	0.232	Caenidae	25.9	0.372
Chironomidae	50.9	1	Ecnomidae	25	0.583
Empididae	46.3	0.116			
Aeshnidae	38.1	0.581			
Hydrobiosidae	33.3	0.206			
Athericidae	33.3	0.349			
Nematoda	33.3	0.588			
Baetidae	25	0.353			

Leptophlebiidae that have a high IV–value in riffles in California, South Africa and SWAustralia but not in MedBasin, where is classified as a pool-specie. The Coleopterans Elmidae and Hydraenidae are present in riffles in the regions where they were found: MedBasin, California and South Africa. The Dipteran Ceratopogonidae is characteristic from riffles in MedBasin and SWAustralia but from pools in California and South Africa. The highly abundant Chironomidae is a riffle-family in MedBasin, South Africa and SWAustralia but not in California. Several non-cased caddisflies as Rhyacophilidae in MedBasin and California, Polycentropodidae in California, Hydrobiosidae in SWAustralia are common in riffles jointly with the stony-case caddisflies as Glossosomatidae. Other cased caddisflies, as Sericostomatidae, have a high IV-value in riffles in MedBasin but in pools in California. On the other hand, Leptoceridae have a high IV-value in riffles in South Africa but in pools in SWAustralia.

Odonata, Heteroptera and Coleoptera are dominant taxa in pools. Dytiscidae, Gerridae, Leptophlebiidae and Culicidae are tolerant lentic families shared between MedBasin and California. At the same time, Dytiscidae is also characteristic and abundant in SWAustralia. California have a longer list of families with a high IV-value compared with MedBasin, with Gomphidae, Cordulegasteridae and Aeshnidae, together with the woody-cased caddisflies Lepidostomatidae, some Limnephilidae and Calamoceratidae. Some Mollusca very abundant in pools in MedBasin as Hydrobiidae are not significantly present in California but others with a high IV-value as Physidae were collected. In southern hemisphere fewer number of Mollusca taxa was found. The Odonata Coenagrionidae is a shared and abundant family in pools in MedBasin and South Africa, whereas Gomphidae is in California and SWAustralia. Ostracoda have been collected in all med-regions, but were more significantly found in pools in California, South Africa and SWAustralia.

Comparisons between common and characteristic community according to habitat preferences between pairs of med-regions were performed and the results are plot in Figure 12. Higher similarities between riffles and pools are observed between regions than the between permanent and temporary sites. All med-regions have convergent responses of the common taxa in front of reophilia, with 80% of similarity between California and South Africa and SWAustralia. MedBasin also have high similarities with the rest of med-regions, with over than 64% with South Africa, and around 70% with California and SWAustralia. On the other hand, the percentage of similarity between South Africa and SWAustralia appears to be lower than the observed when permanent and temporary conditions are compared.

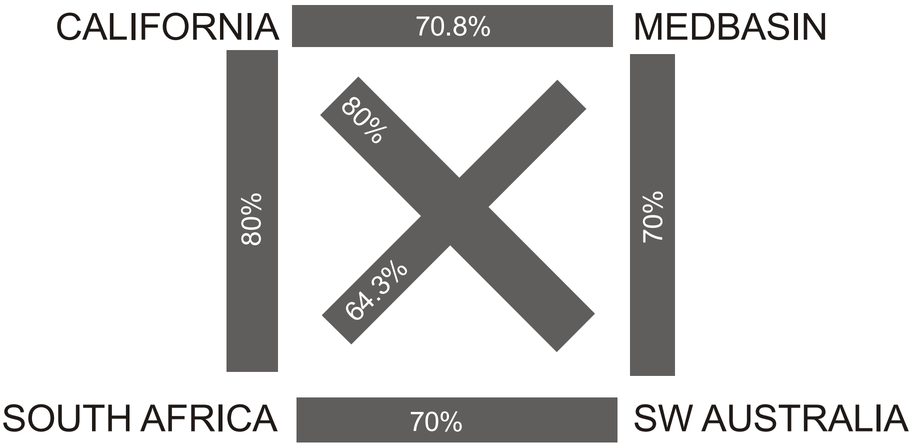


Figure 12. Percentages of similarity between med-regions considering common abundant and representative (IV-value) taxa in riffles and pools habitats.

DISCUSSION

Traditionally, convergence in ecology has had a deterministic framework, where communities developed under similar conditions would have a common structure (Cody & Mooney, 1978). However, several approaches argue that historical factors and intrinsic indeterminism can imply divergence even under similar environments (Samuels & Drake, 1997). The scale of study is important to check for global convergences and divergences between regions, as some scales of observation can obscure others (Samuels & Drake, *op. cit.*). Overall, our study has focused at two levels with the mediterranean climate as a common denominator: regional and local.

Regional scale: historical factors

Appropriate taxonomical sufficiency in aquatic studies has been highly discussed in stream ecology, and especially in bioassessment (Resh & Unzicker, 1975; Cranston, 1990; Marchant *et al.*, 1995; Bowman & Bailey, 1997). Although the use of a low taxonomical resolution implies a gain in precision and information in the responses (Furse *et al.*, 1984; Resh *et al.*, 1995), at large scale, when different regions in the world are compared in taxonomical composition and ecological responses, higher taxonomical levels can be more useful as speciation have acted in a different way in each region. On the other hand, several authors have demonstrated that ecological patterns observed at higher taxonomical levels are equivalent to the ones at genus or species (e.g. Furse *et al.*, 1984; Ferrano & Cole, 1992; Rutt *et al.*, 1993; Marchant *et al.*, 1995). However, because the high speciation present in some families (e.g. Leptoceridae in southern hemisphere —de Moor, 1988, 1997) some divergences observed between med-regions could be attributed to dissimilar ecological responses because of the existence of different genus and species between regions. When detailed taxonomical information is not available, comparisions at genus or species level are impossible. In this case, as in our study, studies at higher taxonomic level may provide interesting insigths about the importance of historical and ecological factors (Ricklefs, 1987).

According to the results obtained, when macroinvertebrate assemblages at family level are studied in the 5 med-regions in the world, the historical factor seems very important in determining macroinvertebrate community of streams in med-regions (see Figure 13 for summary). Convergences found between med-regions in macroinvertebrate community are unlikely related to the climate because of the short history of the mediterranean climate (Alxelrod, 1973; Suc, 1984), and seems to be related to previous historical factors. Notable differences are found between northern and southern hemisphere, as the early breakup between Laurasia and Gondwanaland during the Cretaceous (70-135 myBP). As in plant communities (Deacon, 1983), macroinvertebrates from boreal med-regions are highly convergent, because the connections between both regions until the Eocene by Bering bridge (Deacon, 1983), whereas macroinvertebrates in southern hemisphere are more divergent between med-regions because the early break up of Gondwanaland in early Cretaceous. This strong convergence observed between MedBasin and California implies lower exclusivity of taxa in both regions at family level. On the other hand, some exclusive families in MedBasin or California have a wider distribution than med-region it self. For instance, Prosopistomatidae or Polymitarcidae from MedBasin are also found in African areas (Edmunds, 1972), and Pteronarcyidae or Peltoperlidae in California have been recorded in other Neartic and Asian regions (Zwick, 2000).

High convergences have been reported in plants between California and Chile because the exchange of taxa through the Panama istm, 3 My ago (Naveh & Wittaker, 1979; Di Castri, 1991). Contrary to that, our study shows that Chilean macroinvertebrate community have a weak convergence with California med-region at family level, what could be related with the faster dispersion of plants in front of invertebrates (Cox & Moore, 1993) and the lowest richness by the insular situation of the country between Andes, Atacama desert and Pacific

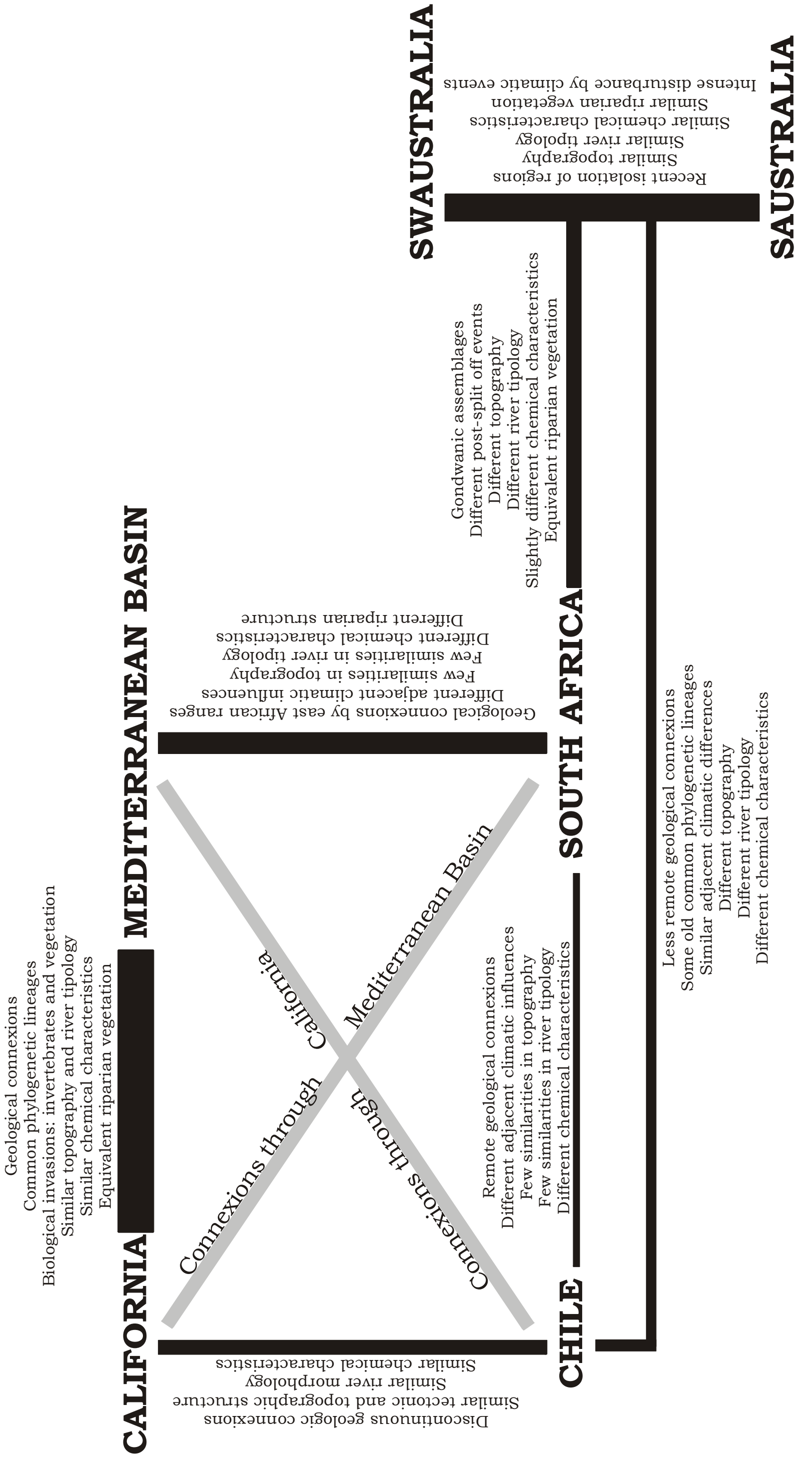


Figure 13. Convergence graph among mediterranean regions. The line width is a representation of the degree of similarity between mediterranean areas.

ocean (Armesto *et al.*, 1997). However, several taxa originated in northern hemisphere are present in Chile and absent in other southern med-regions, as Limnephilidae, Psychomyiidae, Perlidae or Notonemouridae (nowadays extinct in northern hemisphere —Zwick, 2000). These cold-temperate fauna could have arrived to Chile through Panama istm and be established because of the local conditions provided by Andes ranges. On the other hand, as in plant community (Naveh & Wittaker, 1979), we found that Chile have a weak convergence between med-regions in southern hemisphere in macroinvertebrates. However, more families are shared with Australia than South Africa because of the connections between the Neotropical and Austral areas until late Cretaceous (Brundin, 1965; Harrison, 1978).

As it has been seen in plants (Cowling, 1992), macroinvertebrate assemblage in South African med-region is more convergent to tropical adjacent areas and northern hemisphere than to Chile or Australia. This relationship with the boreal area would indicate an active migration during Miocene or Pliocene, of organisms originated in the Paleartic and Neartic area through the south by the African uplands, as for example some coldstenotermous macroinvertebrates (Heptageniidae, Notonemouridae, Lepidostomatidae and Goeridae). Moreover, some convergences between South Africa and the Holartic area as the Tricorythidae originated in Africa (Edmunds, 1972), would explain that exchange in a different direction were also probable. However, not all taxa originated in northern hemisphere or tropical adjacent areas are found in the med-region. For instance, Perlidae, Sialidae, Oligoneuridae, Palaemonidae, Calamoceratidae or Psephenidae lack in Western Cape, although that does not imply a lost of convergence between northern hemisphere areas. In spite of that, we have found few similarities between South Africa and Australia (Notonemouridae, Chlorolestidae, Protoneuridae with SAustralia, and Athuridae and Amphisopodidae with SWAustralia). Day *et al.* (2001) pointed out that more convergences in crustaceans should have existed before the end of Cretaceous when an important drought affected South Africa, extinguishing many taxa.

Although closer in space, SWAustralia and SAustralia are more divergent in macroinvertebrates than California and MedBasin. This fact can be explained by the presence of an extreme arid period around 18000 yBP ago (DeDeckker, 1986) that affected SWAustralia region, implying several taxonomical extinctions and isolating this area from the east by 1000 km of desert. Consequently, further colonizations of macroinvertebrates from the east coast to the southwest were difficult and a low number of fauna in the southwest has been noticed by Bunn & Davies (1990).

In spite of these observed divergences between macroinvertebrate assemblage in med-region, numerous ubiquitous taxa are present, what implies the existence of similar evolutionary mechanisms of dispersion, extinction and adaptation of the taxa along time (Deacon, 1983). Because of the dispersion and colonization of one organism depends on the environmental conditions and life cycles (Cox & Moore, 1993), organisms with short life cycles, continuous reproductions and aerial phases should be easily dispersed, and therefore they will have a wider distribution (Williams & Feltmate, 1993). Baetidae, Caenidae, Leptophlebiidae, Leptoceridae, Hydropsychidae, Oligochaeta and almost all dipterans are ubiquitous taxa, and most of them have been considered as organisms easily to disperse because their morphological and reproductive traits (for example see Gray, 1981; Gray & Fisher, 1981; Fisher *et al.*, 1982). Moreover, most of these taxa are characterized by having a very old origin (e.g., Baetidae, Caenidae and Leptophlebiidae) in contrast with others with a local distribution (e.g., Teloganodidae — Edmunds, 1972).

Historical factors are important to understand taxonomical convergences and divergences, but the viability and success of one taxa in one new region will depend on the local and environmental conditions (Resh & Solem, 1996). In that sense, Ball (1975) distinguishes between an analytical (Historical Biogeography) and an empirical biogeography (Ecological Biogeography). Thus, the abundance of EPT in Northern hemisphere and Chile respect other areas could be interpreted by the mountain river typology of some rivers flowing from high mountains near the coast (Sierra Nevada in California, Andes in Chile and Sierra Nevada, Pyrenees, Apennines, Atlas,... in Med-Basin), that let the establishment of species adapted to steep, cold and fast flowing rivers. On the other hand, even though some mountainous and high gradient rivers with cold waters are present in South Africa and SAustralia, the low EPT/OCH is explained by the poor contribution of Plecoptera in these regions because of biogeographical factors (Zwick, 2000), instead of environmental ones. This difficulty to discern between ecological and historical factors has been emphasized by Endler (1982), but both have to be present to understand community structure and composition (Ricklefs, 1987; Menge & Olson, 1990).

Local scale: Ecological factors and the spatio-temporal variability

In our study and according to the measured factors in reference conditions (without human disturbance), pH is a key variable to diferenciate med-regions. Calcareous geology in mediterranean basin (di Castri, 1981) is the responsible of a high pH in its rivers and streams (Toro *et al.*, (in press)), whereas heavily washed soils in South Africa and SWAustralia (Specht & Moll, 1983), provide a high acidity in reference conditions. In South Africa, fynbos vegetation accentuates this phenomenon supplying highly concentrations of humic acids to the water (Midgley & Schafer, 1992). This gradient of med-regions in pH is followed by temperature in a contrary sense, related with local and microclimatic factors. For example, sites located near high mountains in California or MedBasin should have a lower temperature than the ones in the plains or coastal areas (Hornbeck *et al.*, 1983; Robles *et al.* (in press)).

This variability of physical and chemical factors and the high diversity in landscape topography between med-regions, influence the presence and abundance of several macroinvertebrate's taxa. Thus for instance, Mollusca are infrequent in South Africa because the acidic and oligotrophic conditions (Harrison & Agnew, 1962; Brown, 1978), but are abundant in Med-Basin localities with a calcareous geology (Martínez-López *et al.*, 1988; Gallardo-Mayenco *et al.*, 1994; Habdija *et al.*, 1995). However, mixed with local factors, historical events can also influence the abundance of some taxa respect others. For example, Leptoceridae and Leptophlebiidae are very abundant in South Africa and SWAustralia, because of its large diversification in southern hemisphere (de Moor, 1988, 1997; Edmunds, 1972). Consequently, a combination of local and historical factors appear, once again, as the responsible of the convergences and divergences observed in med-regions.

Disturbance (e.g., floods and droughts) is a key element to understand biodiversity in streams (Resh *et al.*, 1988; Vinson & Hawkins, 1998) independently of historical events. The response of a system to disturbance depends on the degree of stability (Wishart, 1998) and its frequency and intensity (Resh *et al.*, 1988). We should expect that annual discharge variation in mediterranean rivers (Gasith & Resh, 1999) could imply similar responses to the effect of temporality between med-regions except in extreme cases (e.g., in a more semiarid or arid areas), where the high unpredictability in the intensity and frequency of the occurrence of rainfall and discharge (Vidal-Abarca, 1990) would emphasize the differences between temporary and permanent sites.

Several comprehensive studies about the effect of drougths have been done in different regions in the world (see Boulton & Suter, 1986; Williams, 1987; Boulton & Lake, 1992ab). This flow disturbance induces an adapted macroinvertebrate community (Williams & Hynes, 1977; Williams, 1987; Delucchi & Peckarsky, 1989; Sommerhäuser *et al.*, 1997) in terms of resilience and resistance (Stanley & Fisher, 1992) with the former more important in temporary streams (Grimm & Fisher, 1989). Studies performed in mediterranean rivers also suggest that, temporary rivers and streams have macroinvertebrates of smaller size with multivoltine life cycles (Bonada *et al.*, Chapter 5), but at the same time adapted taxa have also developed.

Disagreements exist comparing differences between richness in permanent and temporary sites. For instance, Wrigth *et al.* (1984) or del Rosario & Resh (2000) found lower richness in temporary than permanent sites, whereas Legier & Talin (1973), Boulton & Suter (1986) or Miller & Golladay (1996) report similar number of taxa. In our case, similar richness has been recorded for all regions among permanent and temporary sites in springtime. But despite the similar species richness between permanent and temporary sites in all regions, several differences appear, specially when SWAustralia is compared with other regions. Bunn & Davies (1990) pointed out that the fauna in SWAustralia is depauperate compared with the one found in the east side of the continent, because the isolation of the SW and the previous history, that caused that permanent taxa with longer life cycles (e.g., Oligoneuridae, Siphlonuridae, Austroperlidae, Eustheniidae, Calocidae or Helicophidae) disappeared in the past, and further colonizations were difficult. Then, the taxa typical from permanent sites are absent in this area, what would explain the similarities between permanent and temporary sites in this med-region, although the higher precipitaion occurred in the area one year before sampling, respect the other med-regions, could be also another reason. On the other hand, Boulton & Lake (1992) studying several temporary sites in Australia and their nearby permanent ones found a significant faunal overlap, not found in other studies in northern hemisphere (Williams & Hynes, 1976; Casey & Ladle, 1979; Wrigth *et al.*, 1984). In that sense, Wishart (1998) suggest that there are different responses to temporality between northern and southern hemisphere, with higher differences between permament and temporary communities in northern because of more stable rivers are present.

Looking for differences between several insect orders, we found riffle taxa (EPT) with higher abundance values in permanent sites, and a mixing of riffle and lentic communities (OCH and some EPT) in temporary ones. That would suggest that differences between permanent and temporary sites are consequence of a different proportion of riffles and lentic habitats. Legier & Talin (1973) in a study in several French mediterranean temporary and permanent rivers pointed out that some lotic taxa were absent in temporary sites, as Rhyacophilidae, Heptageniidae, Goeridae or Perlidae, and a similar pattern we have found in Med-Basin, California and South Africa. On the other hand, Boulton & Lake (1992a) studyiong several tmeporary sites, found more taxa and individuals in pools than in riffles. Consequently, in springtime even though the temporary rivers still present some riffles and pools, a major presence of pools taxa indicates a restructuring community adapting to intermittency and ephemerally of waters in summertime.

From our results, differences in taxa richness and abundance between riffles and pools (R vs. L) seem to be more important than temporality and consequenlty more convergent between med-regions. In fact, Delucchi (1988) noticed higher differences between riffles and pools than temporary and permanent sites, which agree with our results.

All sampled med-regions have a similar number of taxa between riffle and lentic habitats, as has been shown in elsewhere (e.g., Scullion *et al.*, 1982; Logan & Brooker, 1983, but see Brown & Brussock, 1991; Boulton & Lake, 1992a or McCulloch, 1986). However, composition differs between habitats looking at order or family assemblage, as has been reported by many studies (e.g., Logan & Brooker, 1983). Riffles in mediterranean rivers hold a higher number of Ephemeroptera, Plecoptera and Trichoptera in front of Odonata, Coleoptera and Heteroptera, because of their different hydraulic requirements (Statzner *et al.*, 1988). This pattern has also been observed in other areas far away from mediterranean regions, as in a more temperate area in England (Scullion *et al.*, 1982) or more arid in North America (McCulloch, 1986). Strong similarities are also observed looking at the exclusive fauna found in riffles and pools, when our results are compared with other studies around the world (e.g., see Rabeni & Minshall, 1977; Armitage *et al.*, 1974; Scullion *et al.*, 1982; McCulloch, 1986; Malmqvist *et al.*, 1993), what would indicate that differences between habitats in macroinvertebrate community are independent of mediterranean climate. However, climatic patterns can influence in the proportion of riffles and pools in a reach along the year, loosing riffles as the drought is coming (Gasith & Resh, 1999; Bonada et al., Chapter 4).

Regional and local richness in mediterranean rivers

In any region, richness of plants or animals is a product of the balance between processes acting at different scales (Ricklefs, 1987; Tonn *et al.*, 1990). Regional richness (by history factors) have been obtained using all accumulated taxa recorded in each med-region, whereas local richness (by ecological factors) may be referred to the number of taxa collected per sampling site.

Traditionally, stream ecologists have focused on the Thienemann's principles (Thienemann, 1954) where richness is a function of frequency and magnitude of physical disturbance, indicating a highest richness at intermediate levels of disturbance (e.g., Minshall, 1988; Sousa, 1994). Poff & Ward (1989) classified North American streams according to degrees of intermittency, flood frequency and predictability and flow predictability suggesting highest richness under high flow predictability by low in high flood and drought frequency. Mediterranean rivers, are characterized by predictable disturbances (floods and droughts) (Gasith & Resh, 1999) what would imply a higher regional richness compare with other climatic regions where floods and droughts are more extreme and less predictible. Consequently, although the intensity and frequency of this discharge disturbance is impredectible (Vidal-Abarca, 1990; Gasith & Resh, 1999) regional richness found in med-regions (as number of family taxa) appears is very high, except for SWAustralia, where historical events constrained a major number of taxa (Bunn & Davies, 1990). Values of richness obtained from this study are difficult to compare with other climatic areas because no comparative studies between climates have been performed. However, some extensive studies performed elsewhere may be useful. Thus, for example, an extensive study in NWAustralia, under two climates, 90 macroinvertebrate families were collected, 77 in the tropical wet-dry climate and 73 and 61 in the desert one (Kay *et al.*, 1999), values lower than the found in med-regions. Studies in plant biology agree with this high biodiversity in med-regions (Raven 1973; Deacon, 1983), what exhibit that under intermediate stress conditions a high biodiversity can be hold. The explanation may be found in the predictability of events (floods and drougths) in the mediterranean climate (Gasith & Resh, 1999) and the presence of resilient and resistant adaptations to these disturbances by evolutionary forces acting since the begining of the earth history.

According to Ricklefs (1987) the relationship between regional and local richness indicate the relative importance of regional and local processess influencing local richness. Thus, if med-regions with different regional richness have similar local richness, local processes are important, whereas if a positive relationship between regional and local richness is present, regional factors dominate. Figure 14 displays the relationship between regional and local richness in the sampled med-regions. The relationship is positive between SWAustralia, South Africa and California. Regional processes are important to determine local diversity in these areas because their different biogeographic history. However, although MedBasin presents the highest regional richness, it displays a highly variable intermediate local richness, indicating that there is a regulation of local richness by local factors. This phenomena does not agree with Shmida (1981) who comparing vegetation of chaparral and coastal sage between Israel and southern California found four time more regional richness and two times local richness in Israel than in California. MedBasin region present a changing topography, landscapes and microclimates (see Plate 2) that originate numerous river types (e.g., ramblas, short and nival-influence rivers, karsts,...). In this situation, different local factors (biotic or abiotic) can act more or less severely modulating richness and making it highly variable between sites. On the other hand, this high variability in river tipology and several historical events may be the responsibles to the highest value of regional richness found in MedBasin. Thereby, the presence of such tipologies could allow the presence and survival of some specific taxa and at the same time modulate local richness.

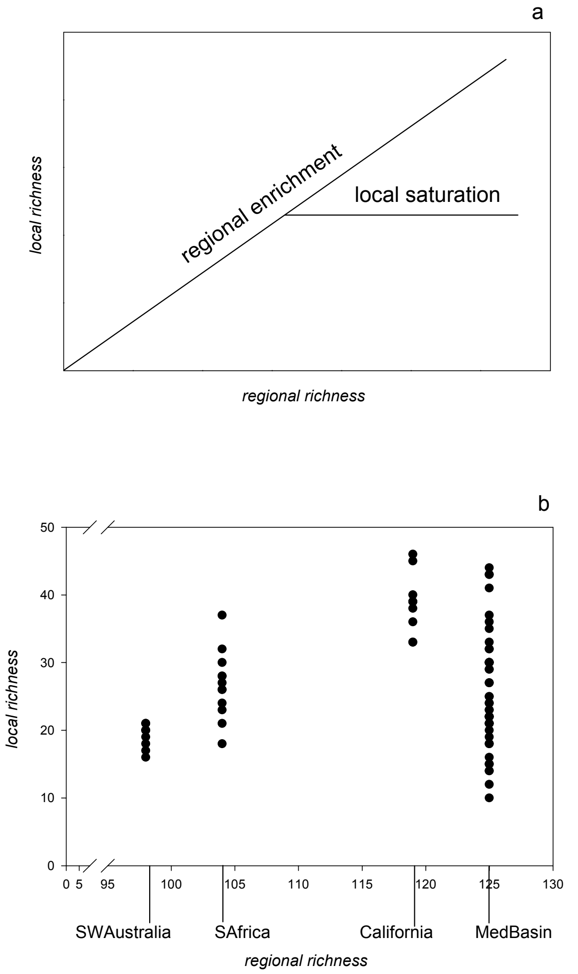


Figure 14. Relationship between regional and local richness. In Figure 14a, model from Ricklefs (1987) is presented. In Figure 14b the application of the model to collected data in med-regions and the approximate curve is plot.

Other convergences and divergences between med-regions

Convergences and divergences between med-regions have been established looking at the communitiy structure. However, communities may display different structure in distant regions, but present similar patterns in feeding or behavioural strategies. Because unavailable data in some med-regions, we were not able to compare trophic relationships under similar climatic conditions. However, some observations can be made from our study. For example, in southern Hemisphere, where the predators Rhyacophilae lack by historical factors, they a replaced by other macroinvertebrates with similar feeding requirements, as the Corydalidae in South Africa. However, in some cases, some feeding strategies are not replaced because again, local factors constrain them. That is the case of South Africa, where its oligotrophic and acidic waters (King *et al.*, 1979) constrain the presence of grazers in headwaters, appearing downstream.

Concluding remarks

Historical and ecological factors have been used in our study to check for differences between macroinvertebrate communities in med-regions. In all cases, northern hemisphere regions have strong convergences compared with the rest of med-regions, and a closer similarity with South Africa than SWAustralia is noticed. Scale of study and the interchange of information between scales have been a problem for ecologists (Levin, 1992). Difficulties are found to define and establish what are large and small scales (Peckarsky *et al.*, 1997). We argue that under the same climatic constrains both historical and local factors are important to macroinvertebrate communities. Convergences or divergences in historical and ecological factors among med-regions let us to understand convergences or divergences in macroinvertebrate community, although other factors as the incidence of non-native macroinvertebrates could affect similarities and differences between med-regions. Consequently, in reference conditions, history, climate, landscape, temporality, habitat and biotic interactions can be considered as filters acting as mechanistic factors in a hierarchical direction, allowing the presence and enhancing the abundance of several species in front of others (Tonn *et al.*, 1990; Poff, 1997). Comparisons in common taxa between med-regions suggest that historical and ecological factors could be more important than climate to determine the abundance of several taxa in a specific habitat or flow condition. However, when such factors let the abundance of some taxa in several regions (e.g., the high pH in California and MedBasin enhance the presence of Mollusca), responses to habitat and temporality between med-regions are highly convergent. From our data, more similarities have been observed between pairs of med-regions in habitat than in flow conditions, suggesting that habitat has more effect on the macroinvertebrate community than temporality, as has been pointed out by Delucchi (1998).

Responses to temporality and habitat in mediterranean rivers suggest the existence of an habitat template (Southwood, 1977; Poff & Ward, 1990; Townsend and Hildrew, 1994) modulated by mediterranean climate, where the evolution acted establishing adaptative convergences in macroinvertebrates between med-regions, whereas divergences may be related to topographic, litologic or historical factors. Further studies focused on biological or ecological species traits should be done to provide more information about similar response under common flow disturbances and habitat heterogeneity independently of similarities and differences between macroinvertebrate assemblages. Moreover, comparative information about the annual and interannual changes of macroinvertebrate community between med-regions would help us to understand better the identity and uniqueness of mediterranean rivers.

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Annex 1. Presence and absence of taxa in each mediterranean region.

		California	MedBasin	Chile	South-Africa	SW Australia	S Australia
PLATIHELMINT	Dugesiidae	1	1	1	1	1	0
	Planariidae	1	1	0	0	0	0
	Temnocephalidae	0	0	1	0	1	1
GORDIIDAE	Gordiidae	1	1	1	1	1	1
OLIGOCHAETA	Oligochaeta	1	1	1	1	1	1
POLIQUETA	Neiridae	1	0	0	0	0	0
	Syllidae	0	0	0	0	0	1
AQUETA	Erpobdellidae	1	1	0	0	0	1
	Glossiphoniidae	1	1	0	0	0	0
	Hirudinidae	1	1	0	1	0	0
	Mesobdellidae	0	0	1	0	0	0
	Richardsonianidae	0	0	0	0	1	1
MOLLUSCA	Amnicolidae	0	0	1	0	0	0
	Ancylidae	1	1	1	1	1	1
	Bithynellidae	0	1	0	0	0	0
	Bithyniidae	0	1	0	0	0	1
	Chilinidae	0	0	1	0	0	0
	Corbiculiidae	1	0	0	1	1	1
	Ferrissiidae	0	1	0	0	0	0
	Hydrobiidae	1	1	0	1	1	1
	Hyriidae	0	0	1	0	1	1
	Lymnaeidae	1	1	1	1	1	1
	Neritidae	0	1	0	0	0	0
	Physidae	1	1	1	1	1	1
	Planorbidae	1	1	1	1	1	1
	Pomatopsidae	0	0	0	0	1	1
	Sphaeriidae	1	1	1	1	1	1
	Thiaridae	1	1	0	1	1	1
	Unionidae	1	1	0	1	0	0
	Valvatidae	1	1	0	0	0	0
	Viviparidae	0	1	0	0	0	1
CRUSTACEA	Aeglidae	0	0	1	0	0	0
	Amphisopodidae	0	0	0	1	1	0
	Anthuridae	0	0	0	1	1	0
	Asellidae	1	1	1	0	0	0
	Astacidae	1	1	0	0	0	0
	Atyidae	1	1	0	1	1	1
	Cambaridae	1	1	0	1	0	0
	Ceinidae	0	0	0	0	1	1
	Cirolanidae	0	0	0	0	0	1
	Eusiridae	0	0	0	0	0	1
	Gammaridae	1	1	1	0	0	0
	Grapsidae	1	1	0	1	1	0
	Hyallelidae	1	0	1	0	0	0
	Hymenosomatidae	0	0	0	0	1	1
	Janiridae	0	0	0	1	1	1
	Mesoveliidae	1	1	0	0	1	1
	Munnidae	0	0	0	1	0	0
	Oniscidae	0	0	0	0	1	1
	Ostracoda	1	1	0	1	1	1
	Palaemonidae	0	1	0	1	1	1
	Paracalliopidae	0	0	0	0	0	1
	Paramelitidae	0	0	0	1	1	1

		California	MedBasin	Chile	South-Africa	SW Australia	S Australia
	Parastacidae	0	0	0	0	1	1
	Perthiidae	0	0	0	0	1	1
	Phreatoicidae	0	0	0	1	1	0
	Potamonautidae	0	0	0	1	0	0
	Protojaniridae	0	0	0	1	0	0
	Samastacidae	0	0	1	0	0	0
	Spelaeogriphidae	0	0	0	1	0	0
	Sphaeromatidae	0	0	0	1	1	0
	Sternophysingidae	0	0	0	1	0	0
	Talitridae	0	0	0	0	0	1
ACARI	Hydracarina	1	1	1	1	1	1
	Oribatidae	1	1	0	0	1	1
EPHEMEROPTERA	Ameletidae	1	0	0	0	0	0
	Amelotopsidae	0	0	1	0	0	0
	Baetidae	1	1	1	1	1	1
	Caenidae	1	1	1	1	1	1
	Coloburiscidae	0	0	1	0	0	0
	Ephemerellidae	1	1	0	0	0	0
	Ephemeridae	1	1	0	0	0	0
	Heptageniidae	1	1	0	1	0	0
	Leptophlebiidae	1	1	1	1	1	1
	Oligoneuriidae	1	1	1	0	0	1
	Onicigastridae	0	0	1	0	0	1
	Polymitarcidae	0	1	0	0	0	0
	Potamanthidae	0	1	0	0	0	0
	Prosopistomatidae	0	1	0	0	0	0
	Siphlonuridae	1	1	1	0	0	1
	Teloganodidae	0	0	0	1	0	0
	Tricorythidae	1	0	0	1	0	0
PLECOPTERA	Austronemouridae	0	0	1	0	0	0
	Austroperlidae	0	0	1	0	0	1
	Capniidae	1	1	0	0	0	0
	Chloroperlidae	1	1	0	0	0	0
	Diamphipnoidae	0	0	1	0	0	0
	Eustheniidae	0	0	1	0	0	1
	Gripopterygidae	0	0	1	0	1	1
	Leuctridae	1	1	0	0	0	0
	Nemouridae	1	1	0	0	0	0
	Notonemouridae	0	0	1	1	0	1
	Peltoperlidae	1	0	0	0	0	0
	Perlidae	1	1	1	0	0	0
	Perlodidae	1	1	0	0	0	0
	Pteronarcyidae	1	0	0	0	0	0
LEPIDOPTERA	Nymphulidae	1	0	0	1	0	0
	Pyralidae	1	1	1	0	1	1
MECOPTERA	Nannochoristidae	0	0	1	0	0	0
	Eomeropidae	0	0	1	0	0	0
MEGALOPTERA	Corydalidae	1	0	1	1	0	0
	Sialidae	1	1	1	0	0	0
NEUROPTERA	Chauliodidae	1	0	0	0	1	0
	Osmylidae	0	1	1	0	0	0
	Sisyridae	1	1	0	1	0	1
COLEOPTERA	Brentidae	0	0	0	0	1	1
	Carabidae	0	0	0	0	1	1
	Colymbetidae	1	1	0	0	0	0

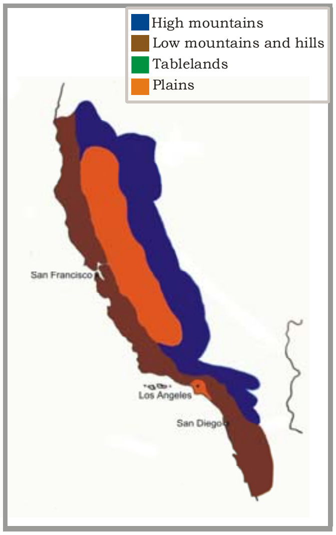
		California	MedBasin	Chile	South-Africa	SW Australia	S Australia
	Crysomelidae	1	0	0	0	1	1
	Dryopidae	1	1	1	1	0	0
	Dytiscidae	1	1	1	1	1	1
	Elmidae	1	1	1	1	1	1
	Georrisidae	0	1	0	0	0	0
	Gyrinidae	1	1	1	1	1	1
	Haliplidae	1	1	1	1	1	1
	Helodidae	1	1	0	1	1	0
	Helophoridae	1	1	0	0	0	0
	Heteroceridae	0	0	0	0	1	1
	Hydraenidae	1	1	1	1	1	0
	Hydrochidae	0	1	0	0	0	1
	Hydrophilidae	1	1	1	1	1	1
	Hygrobiidae	0	1	0	0	0	1
	Limnebiidae	0	1	0	0	0	0
	Limnichidae	1	0	1	1	0	1
	Noteridae	0	1	0	1	0	0
	Psephenidae	1	0	1	0	0	1
	Scirtidae	0	0	0	0	1	1
	Staphylinidae	0	0	0	0	1	1
HETEROPTERA	Aphelocheiridae	0	1	0	0	0	0
	Belastomatidae	1	0	1	1	0	1
	Corixidae	1	1	1	1	1	1
	Gerridae	1	1	1	1	1	1
	Hebridae	1	1	0	1	1	1
	Hydrometridae	1	1	0	1	1	1
	Naucoridae	1	1	0	1	1	1
	Nepidae	1	1	0	1	1	1
	Notonectidae	1	1	1	1	1	1
	Ochteridae	0	0	0	0	0	1
	Pleidae	1	1	0	1	1	1
	Saldidae	1	0	0	0	0	1
	Veliidae	1	1	0	1	1	1
ODONATA	Aeshnidae	1	1	1	1	1	1
	Calopterygidae	1	1	1	0	0	0
	Chlorophydae	0	0	0	1	0	0
	Chorolestidae	0	0	0	1	0	1
	Coenagrionidae	1	1	1	1	1	1
	Cordulegasteridae	1	1	0	0	0	0
	Corduliidae	0	1	1	1	1	1
	Gomphidae	1	1	1	1	1	1
	Hemicorduliidae	0	0	0	0	0	1
	Lestidae	1	1	1	1	1	1
	Libellulidae	1	1	1	1	1	1
	Megapodagrionidae	0	0	0	0	1	1
	Petaluridae	0	0	1	0	1	0
	Platycnemididae	0	1	0	1	0	0
	Protoneuridae	0	0	0	1	0	1
	Synthemidae	0	0	0	0	1	1
	Telephlebiidae	0	0	0	0	0	1
TRICHOPTERA	Atriplectididae	0	0	0	0	1	1
	Beraeidae	0	1	0	0	0	0
	Brachycentridae	1	1	0	0	0	0
	Calamoceratidae	1	1	1	0	0	1
	Conoesucidae	0	0	0	0	0	1

		California	MedBasin	Chile	South-Africa	SW Australia	S Australia
	Dipseudopsidae	0	0	0	1	0	0
	Ecnomidae	0	1	1	1	1	1
	Glossosomatidae	1	1	1	1	0	1
	Goeridae	1	1	0	1	0	0
	Helicophidae	0	0	1	0	0	1
	Helicopsychidae	1	0	1	0	0	1
	Hydrobiosidae	0	0	1	0	1	1
	Hydropsychidae	1	1	1	1	1	1
	Hydroptilidae	1	1	1	1	1	1
	Hydrosalpingidae	0	0	0	1	0	0
	Lepidostomatidae	1	1	0	1	0	0
	Leptoceridae	1	1	1	1	1	1
	Limnephilidae	1	1	1	0	0	0
	Molanidae	0	0	1	0	0	0
	Odontoceridae	1	1	1	0	0	1
	Petrothrincidae	0	0	0	1	0	0
	Philopotamidae	1	1	0	1	1	1
	Philorheithridae	0	0	0	0	1	1
	Pisuliidae	0	0	0	1	0	0
	Plectrotarsidae	0	0	0	0	1	0
	Polycentropodidae	1	1	1	1	1	1
	Psychomyiidae	1	1	1	0	0	0
	Rhyacophilidae	1	1	0	0	0	0
	Sericostomatidae	1	1	1	1	0	0
	Tasimiidae	0	0	0	0	0	1
	Uenoidae	1	1	0	0	0	0
	Barbarochtharidae	0	0	0	1	0	0
DIPTERA	Anthomyidae	1	1	0	1	1	1
	Athericidae	1	1	1	1	1	0
	Blephariceridae	1	1	1	1	0	0
	Ceratopogonidae	1	1	1	1	1	1
	Chironomidae	1	1	1	1	1	1
	Culicidae	1	1	1	1	1	1
	Dixidae	1	1	1	1	1	1
	Dolichopodidae	1	1	0	1	1	1
	Empididae	1	1	1	1	1	1
	Ephydridae	1	1	1	1	1	1
	Limoniidae	1	1	1	0	1	0
	Psychodidae	1	1	1	1	1	1
	Ptycopteridae	0	1	1	1	0	0
	Scatopsidae	0	0	0	0	0	1
	Sciomyzidae	1	1	0	1	1	1
	Simuliidae	1	1	1	1	1	1
	Stratiomyidae	1	1	1	1	1	1
	Syrphidae	1	1	1	1	1	1
	Tabanidae	1	1	1	1	1	1
	Tanyderidae	0	0	1	1	0	0
	Thaumaleidae	1	1	0	0	1	1
	Tipulidae	1	1	1	1	1	1

Plate 1. Characteristics of the mediterranean region in California.

Climatic features

Location and latitude in almost all California, south of Oregon and north of Mexico (1), 28-44°N (2).
Extension of med-region around 250.000 km2 (2)
Rank of precipitation from 150mm/y to 1800mm/y (1) with snow in the high mountains of Sierra Nevada.
Months with highest rain between November and March (3).
Range of altitude between 0 to >4000m.
Population of 27.000.000 inhabitans (4)



Basin characteristics

Geology composed by metamorphosed, granites and sedimentary deposits (2).
Landscape and topography composed by Coast, Transverse and Peninsula ranges, Great or Central Valley and a more alpine area in western side of Sierra Nevada, Klamath and Cascade mountains (5&6). Coastal plains scarce.
Vegetation with coniferous trees and meadows in alpine areas, deciduous trees in wet areas, redwood formation in northern California (*Sequoia sempervirens*) and sclerofillous and evergreen trees and shrubs (called "chaparral"), savannas or dry steppe in drier areas (2&4).

Abiotic river properties

Annual discharge peak in winter but also in spring in nival influenced rivers (7). Discharge can be affected by El Niño event (8).
Physical and Chemical properties: oligotrophic rivers with high pH (9).
River and stream typologies: short and steepe streams and rivers from coastal ranges longer, steepeness and wider from inland mountains; karstic rivers in southern California (8).
Riverbed substrate composed by boulders, cobbles, gravels in headwaters and sands and silt downstream. Some bedrock rivers in southern California (10&11).

Biotic river properties

Periphyton community highly diverse, abundant and productive.
Macroinvertebrate community highly diverse but lacks of families present in other areas of North America. Some non-native macroinvertebrate's families as Corbiculiidae and Grapsidae.
Fish community is highly endemic with 115 taxa (12) closer to European fish fauna than to that of eastern North America (12). Several non-native species are present as *Gambusia affinis,G. holbrooki, Micropterus salmoides, Alosa sapidissima, Lepomis macrichirus*,...(12&14).
Alloctonous material reach riverbed in autumn, although in undisturbed areas where riparian vegetation unable to survive, sclerofillous leaves arrive to the river along the year (9). Higher decomposition rates in deciduous leaves (15).
Riparian Vegetation mainly with deciduous trees and shrubs (16) as *Salix sp., Alnus sp., Corylus cornuta, Populus sp.* or *Fraxinus* sp. Highly altered by non-native species introductions as *Arundo donax, Nicotiana sp.*, or *Tamarix sp.*

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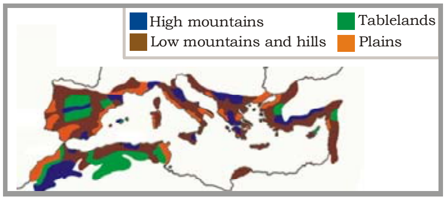
Plate 2. Characteristics of the mediterranean region in Mediterranean Basin.

Climatic features

Location and latitude in Mediterranean Sea basin excluding Black Sea, Caspian Sea and Persian Gulf (1), 31-45°N (2).
Extension of med-region around 1.100.000 km2 (2)
Rank of precipitation from <300mm/y to 2500mm/y (3) with snow in the high mountains
Months with highest rain between December and January in Southern Europe and in October through the north. A second peak in spring is also present (2)
Range of altitude between 0 to 3500m (2)
Population of 150.000.000 inhabitans (4)



Basin characteristics

Geology mainly with limestone (5) but some metamorphosed, granites and sedimentary deposits (2).
Landscape and topography composed by high mountains (Alpes, Apenninnes, Blakans, Pyrenees, Iberian and Baetic Cordilleras, Taurus Mountains, Cèdres, Atlas, Rif and Kabylie Mountains) and lower hills and mountains sometimes separated by tablelands. Coastal plains frequent.
Vegetation with coniferous trees in alpine areas, deciduous trees in wet areas, sclerofillous and evergreen trees and shrubs (called "maquia" and "garrigue"), savannas or dry steppe in drier areas (2).

Abiotic river properties

Annual discharge peak. Two annual peaks, in spring and autumn (6 & 22).
Physical and Chemical properties: in siliceous rivers and streams, neutral pH and oligotrophic waters (7), whereas in more calcareous areas higher pH and less oligotrophic waters (8). High natural salinity (by sulphates and chloride) in some semiarid areas (9,10&11).
River and stream typologies: short and steepe streams from coastal ranges longer and wider rivers from inland mountains; karstic rivers frequent (12&13); highly ephemeral rivers called "oueds", "ramblas", "wadis", "torrents" or "barrancos" (14). Some deltas plains are present as in Po, Rhône, Ebre rivers.
Riverbed substrate composed by boulders, cobbles, gravels and bedrock in headwaters and sands and silt downstream.

Biotic river properties

Periphyton community highly diverse, abundant and productive.
Macroinvertebrate community highly diverse (15) and abundant in European area compare with African one (6&16), although a high endemism is present in both regions (6&17). Northern rivers and streams dominated by EPT communities whereas more Ephemeroptera and Coleoptera are present increasing aridity through the south (18). Some non-native macroinvertebrate's species as *Procambarus clarkii* and *Potamopyrgus jenksii.*
Fish community higly diverse, endemic (80% of the exclusive freshwater species) compared with the rest of Europe (19). Several non-native species are present as *Oncorhyncus mykiis, Micropterus salmoides, Esox lucius, Carassius auratus, Cyprinus carpio, Gambusia holbrooki, Alburnus alburnus, Hucho hucho, Cichlasoma facetum* and others (19)
Alloctonous material reach riverbed in autumn with a second peak between January and April (20), although in undisturbed areas where riparian vegetation unable to survive, sclerofillous leaves arrive to the river along the year. Higher decomposition rates in deciduous leaves compared with sclerofillous ones (21).
Riparian Vegetation mainly with deciduous trees and shrubs as *Salix* sp., *Alnus glutinosa, Ulmus sp., Corylus avellana, Populus* sp., *Fraxinus* sp or *Tamarix* sp. Highly altered by non-native species introductions as *Arundo donax, Nicotiana sp., Robinia pseudoacacia, Platanus hispanica or Ailanhus altissima.*

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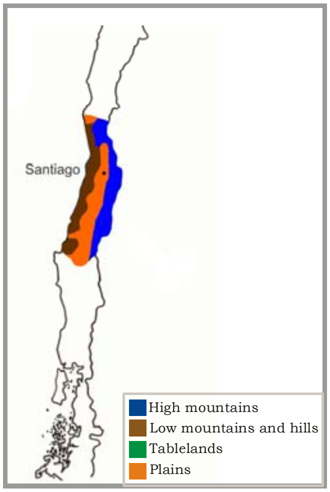
Plate 3. Characteristics of the mediterranean region in Chile.

Chile

Climatic features

Location and latitude in Central Chile, 29-40°S
Extension of med-region around 70.000 km2 (1)
Rank of precipitation from 25mm/y to 2100mm/y (2) with snow in the Andes ranges
Months with highest rain between April and September
Range of altitude between 0 to >5000m(3)
Population of 11.000.000 inhabitans (4)



Basin characteristics

Geology with metamorphosed sediments and igneous batholithic rocks in Andes; sediments in Central Valley; and metamorphosed and granites deposits in Coastal ranges (3).
Landscape and topography composed by coastal ranges, central valley and west side of Andes ranges (3).Coastal plains scarce.
Vegetation constituted by a semidesertic formation called "selva valdiviana"; an esclerofillous and evergreen trees and shrubs (called "matorral"); and woodlans with the deciduous *Nothofagus* sp, and the evergreen *Drimys winteri*. (4&5).

Abiotic river properties

Annual discharge peak in winter months, annually influenced by El Niño event (6)
Physical and Chemical properties: oligotrophic, soft and neutral waters (7,8&9)
River and stream typologies: streams from coastal ranges are short, steepe and small (called "quebradas") whereas rivers from Andes ranges are longer, wider flowing straight to the sea (3&8).
Riverbed substrate composed by boulders, cobbles and gravels in headwaters and sediments downstream (3)

Biotic river properties

Periphyton community present in low abundances (10)
Macroinvertebrate community poorly known compare with other med-regions. Several taxonomical works have been done in Plecoptera (11&12), Trichoptera (13) and Chironomidae (14) and ecological studies are increasing (15). The plecopterans Austronemouridae and Diamphipnoidae are endemic.
Fish community highly diversified with 6 endemic families from Central Chile (*Trichomycterus areolatus, Percilia gillissi, Cauque mauleanum, Basilichthys australis, Cheirodon australe* and *Brachygalaxias bullocki*), 1 present in Central Chile and South of Argentina (*Percichthys trucha*) and another shered with Argentina, New Zealand, Australia and Tasmania (*Galaxias maculatus*). Several non-native species are present as *Salmo trutta, Oncorhyncus mykiis, Ciprinus carpio* and *Gambusia affinis holbrooki*) (8).
Alloctonous material reach riverbed in summer except for woodland forests.
Riparian Vegetation with evergreen and deciduous trees as *Drimys winteri* and *Salix chilensis* and several shrubs as *Myrceugenella chequen* and *Aristotelia chilensis*.Highly altered by non-native introductions of *Pinus radiata* (16)

References

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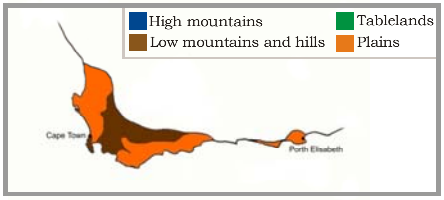
Plate 4. Characteristics of the mediterranean region in South Africa.

Climatic features

Location and latitude in South-western Cape, 32-35°S.
Extension of med-region around 40.000 km^2 (1).
Rank of precipitation from 230mm/y to >2500mm/y (2) with snow unfrequent.
Months with highest rain between April and September
Range of altitude between 0 to 2300m (3).
Population of 3.400.000 inhabitans (4).



Basin characteristics

Geology with sandstones and shales (3) with acidic and low in nutrients soils (5).
Landscape and topography composed by plains and coastal (Table Mountain) and inland ranges (Franschoek and Drakenstein Mountains) separated from the Cretaceous (6).
Vegetation dominated by fynbos biome (7&8) with evergreen and sclerofilous shrubs highly endemic (9) and divided in mountain and coastal fynbos, coastal renosterveld and strandveld (7).

Abiotic river properties

Annual discharge peak in winter months.
Physical and Chemical properties: acid and oligotrophic headwaters (10) with brown colour (11), but clearer, higher in nutrients and pH downstream (10).
River and stream typologies: c
Riverbed substrate composed by boulders, bedrock, cobbles and gravels in headwaters and stones, pebbles and coarse sand downstream (13).

Biotic river properties

Periphyton community scarce (14) with some macrophytes abundant.
Macroinvertebrate community highly endemic with Gondwanic origin (15&16) but lower in diversity compare with other South African rivers. Presence of taxa adapted to a low fish diversity and abundance (16).
Fish community low in diversity and abundance with some non-native species as *Salmo trutta, Tilapia* sp., *Lepomis macrochinus, Ciprinus carpio, Micropterus dolomieu* and *Micropterus salmoides* (17&18).
Alloctonous material reach riverbed in summer. Low decomposition rate (10&14).
Riparian Vegetation shrubby with Prionium serratun, *Metrosideros angustifolia* and *Brabejum stellatifolium.* Non-native species as *Acacia melonoxylon, Quercus robur, Eucaliptus* sp. and *Hakea* sp. are present (19&20).

References

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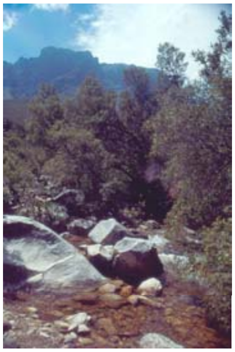
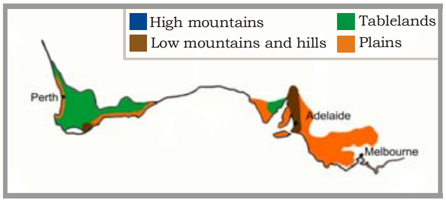


Plate 5. Characteristics of the mediterranean region in Australia.



Climatic features

Location and latitude in South-Western Australia (WA) and South Australia (SA and NSW) (1,2&3) disconnected by 1000km, 28-37°S (4).
Extension of med-region around 350.000 km2 (4)
Rank of precipitation from 300mm/y to 1400mm/y (5&6) without snow.
Months with highest rain between April and November.
Range of altitude between 0 to 582m in SW-Australia (7) and to 1300m in S-Australia (8).
Population of 3.000.000 inhabitans (9)

Basin characteristics

Geology composed by sandstones and granites, quarzites and sedimentary deposits (8).
Landscape and topography with a soft relief in SW-Australia with coastal plains an inland plateaus (Darling Plateau) and more abrupt in S-Australia with Flinders Ranges (7).
Vegetation with by sclerofillous and evergreen shrubs and trees in the coast (called "health" and "mallee"), and Jarrah and Marri forest in the inland plateau in SW-Australia, with *Eucaliptus diversicolor* and *E. marginata* as dominant species (9) . Highly endemic (10).

Abiotic river properties

Annual discharge peak in winter months between June and November (11).
Physical and Chemical properties: oligotrophic rivers with slightly low pH (11).
River and stream typologies: slightly steep rivers in S-Australia coming from Flinger Ranges but steepeness streams in SW-Australia flowing from the Darling Plateau to the coast. A big river system "Murray-Darling River" present in S-Australia.
Riverbed substrate composed by gravel and sand with some large rocks (2)

Biotic river properties

Periphyton community scarce and slightly productive (12)
Macroinvertebrate community depauperate in SW-Australia respect S-Australia (2,12&13). Some Gondwanic relicts as some species of the crayfishes *Cherax* sp. and *Engaewa* sp. (14).
Fish community highly diverse in the Murray-Darling river system. In South Western Australia the community is dominated by *Galaxias occidentalis, Bostockia porosa* and the endemic *Edelia vittata*. Several non-native species are present as *Oncorhynkus mykiss, Gambusia holbrooki* and *Perca fluviatilis*
Alloctonous material reach riverbed in summer (15&16). Few shredders to process CPOM (17).
Riparian Vegetation mainly sclerofillous trees and shrubs as *Dodonea* sp., *Banksia* sp., *Hakea* sp., *Trymalium floribundum, Melaeuca* sp., *Callitris sp. Angianthus* sp., *Eragrostis* sp., and several *Eucaliptus* sp. Altered by non-native introductions of *Pinus* rsp *Mimosa pigra* are common (18).

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Chapter 4

EFFECTS OF THREE DIFFERENT MACROHABITATS ON THE MACROINVERTEBRATE ASSEMBLAGE IN MEDITERRANEAN STREAMS.

INTRODUCTION

Stream ecosystems are organized in a hierarchical framework at different scales of observation (Frissell *et al.*, 1986; Church, 1996). Each level of organization constrains presence and abundance of biota in a different way, because different mechanistic filters operate (Poff, 1997). Habitat has been considered as one important factor in the regulation and organization of biota (Southwood, 1977; 1988; Townsend & Hildrew, 1994), and its spatial and temporal heterogeneity have been associated to different organisms' structure and responses (Southwood, 1977; Townsend and Hildrew, 1994). However, from the static (substrate) and dynamic (flow) features included in the habitat concept, the hydraulic environment has been considered as the main factor explaining distribution of aquatic invertebrates (Statzner *et al.*, 1988). Consequently, at reach scale, riffles and pools have been identified as the major macrohabitats present in flowing rivers and affecting to organisms (Carter & Fend, 2001).

Traditionally, stream ecologists have been interested in how physical factors controlling riffles and adjacent pools can affect the biota. Consequently, numerous studies have been carried out with macroinvertebrates (Logan & Brooker, 1983; Brown & Brussock, 1991; Boulton &

Lake, 1992; Cooper *et al.*, 1986; Angradi, 1996; Ribera & Vogler, 2000; Carter & Fend, 2001), periphyton (Keithan & Lowe, 1985; Rosenfeld & Hudson, 1997; Whitledge & Rabeni, 2000) and fishes (Young, 2001; Inoue & Nunokawa, 2002). Overall, differences between riffles and pools have been associated to abiotic and biological aspects (Brown & Brussock, 1991). Although agreements have been observed in the physical differences between riffles and pools (different velocity, particle size, depth, chemistry…), divergences in macroinvertebrate structure and composition of biota are not always totally correlated with the environmental factors measured. Similar number of taxa between riffles and pools have been reported by several authors (Egglishaw & Mackay, 1967; Armitage *et al.*, 1974; Harrel, 1969; Logan & Brooker, 1983), whereas in other cases riffles are richer (Brown & Brussock, 1991; Carter & Fend, 2001) or poorer than pools (McCulloch, 1986; Boulton & Lake, 1992). Differences in richness between both habitats have been associated to habitat stability (McCulloch, 1986; Boulton & Lake, 1992), annual peak discharge and reach gradient (Carter & Fend, 2001), although other factors as different sampling methodologies and the taxonomical level used could be important (Logan & Brooker, 1983). The uniqueness of each macrohabitat in terms of macroinvertebrates have been noticed by several authors (e.g., Scullion *et al.*, 1982; McCulloch, 1986), although a significant overlap in composition is also found because in practice both habitats are not as discrete as can be presumed (see Rabeni *et al.*, 2002). However, few of these studies have been done in intermittent rivers (Brown & Brussock, 1991; Boulton & Lake, 1992), and thereby the isolated pool as a macrohabitat different to the riffle-pool sequence has been widely neglected in most of the studies.

In mediterranean regions, rivers are characterized by a high annual and interannual discharge variation that might imply floods and droughts (Molina *et al.*, 1994; McElravy *et al.*, 1989; Gasith & Resh, 1999). Consequently, rivers and streams are affected by seasonal natural disturbances in discharge that eliminate and generate different habitats (Lake, 2000). When a drought period is coming, riffle-pool sequences change to a dominance of series of isolated pools before they dry up (Boulton & Lake, 1992; Williams, 1996; Gasith & Resh, 1999; Lake, 2000). Thereby, three macrohabitats can be identified: riffles, pools connected to riffles and isolated or disconnected pools. This change of river patchiness along time is associated to the natural discharge variability and can be more or less important depending on the river characteristics (Lake, 2000; Bonada *et al.*, Chapter 5). Consequently, rivers subjected to mediterranean climate can have at the same time riffles, adjacent and isolated pools, and this situation may remain for days or months depending of many factors (e.g., annual climate or substrate), indicating the strong relationship between spatial and temporal heterogeneity (Bonada *et al.*, Chapter 5).

Hence, the aims of our study is (1) to relate macroinvertebrate community structure and taxa richness to three different macrohabitats (riffles, connected pools and isolated pools) in a mediterranean area and (2) to know if pools adjacent to riffles act as an intermediate habitat between riffles and isolated pools in terms of macroinvertebrate assemblage.

METHODOLOGY

Sampling sites

Macroinvertebrate samples were collected from 19 reference sampling sites in the mediterranean area of northern California during spring 2002. A total of 9 sites (from 8 different rivers) were intermittent during the sampling period with disconnected pools remaining, whereas the rest (10 sites from 10 different rivers) had some flowing water with pools connected to the riffles and are located in headwaters and midstream reaches (see Bonada *et al.*, Chapter 3).

Sites were distributed in the inland mountains of Sierra Nevada, and the coastal ranges north and south of San Francisco (Figure 1). Localities in the Sierra Nevada are reaches with fast flowing waters, in forested basins, medium slopes and substrates composed by boulders and cobbles. The riparian vegetation is dominated by *Alnus* sp., *Salix* sp., *Populus* sp. with some *Pinus lambertiana* and *Pseudotsuga menziesii* from the adjacent coniferous forest. In northern coastal ranges, rivers have high slopes with coarse substrate except in San Geronimo river where gravels, sand and bedrock are important. Riparian vegetation is dominated by *Quercus lobata, Alnus* sp.*, Corylus cornuta, Sequoia sempervirens* and *Umbellularia californica.* Through the south and near the coast, sampled rivers are short, small and steep. Substrates are similar to the ones in the northern coasts. The riparian vegetation is composed by *Quercus lobata, Platanus racemosa, Juglans hindsii, Populus* sp.*, Salix sp., Alnus* sp.*, Corylus cornuta* and *Umbellularia californica.*

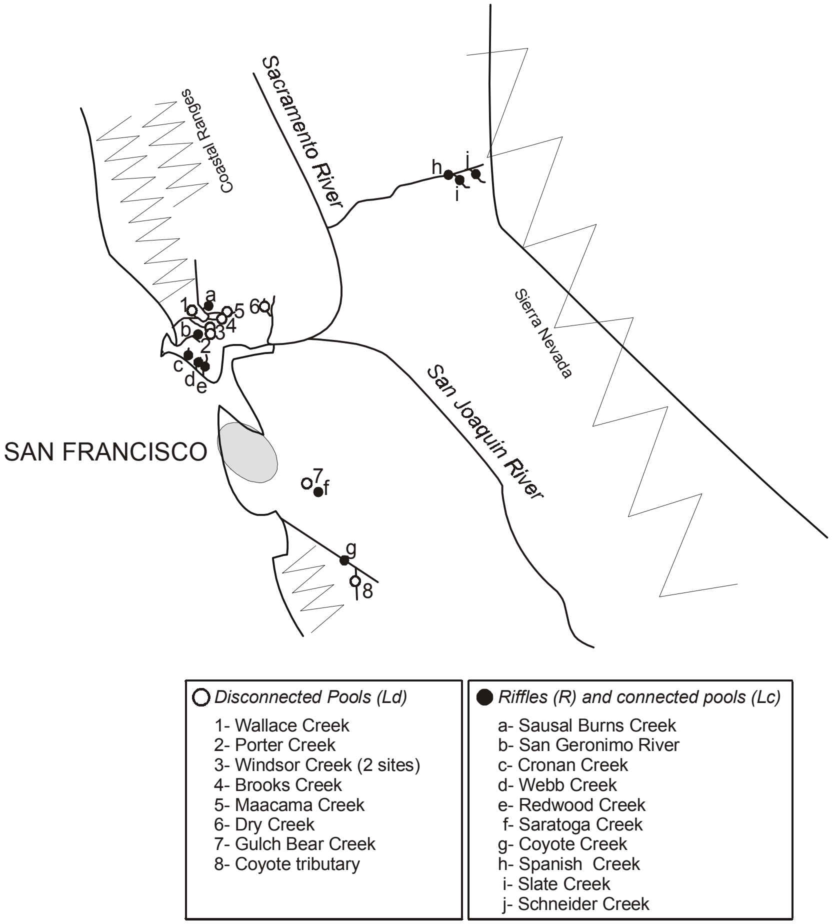


Figure 1. Sampling area.

Sampling procedure

Localities were sampled according to the GUADALMED Project methodology (Bonada *et al.*, Chapter 1; Jáimez-Cuéllar, in press). In each site, pH, temperature, oxygen, conductivity and discharge was recorded. The diversity of habitat was assessed according to the index of habitat (IHF) proposed in Pardo *et al.* (in press). This index varies between 0 and 100 (higher the value, higher is the diversity of habitats present) and evaluates the presence of different substrates, embededness, velocity regimes, instream vegetation and litter cover. Macroinvertebrates samples were collected with a kick net of 250 μm mesh size from riffles (R) and lentic (Lc) habitats in flowing reaches or from disconnected pools (Ld) in intermittent streams. Samples were firstly examined in the field, and successive samples in both habitats are taken until no more families were found by the observer. Several invertebrates seen in the field but not collected in the sample were also recorded, as the large Heteroptera and Coleoptera. All macroinvertebrate samples were preserved in alcohol 70%, sorted in the lab and identified at family level. Because of the semiquantitative nature of samples, a rank of abundances was recorded for each taxon: 1 from 1-3 individuals, 2 from 4-10, 3 from 11-100 and 4 for more than 100 individuals.

Data analysis

Differences between the three habitats have been analyzed using the number of taxa and the index EPT/(EPT+OCH) (EPT=Ephemeroptera, Plecoptera and Trichoptera and OCH=Odonata, Coleoptera and Heteroptera). Because not all data had a normal distribution and homogeneity of variances, a non-parametric Kruskal-Wallis by ranks tests was used to test significant differences between habitats. The same analysis was used to check for differences between flowing and intermittent reaches in physical and chemical parameters. Samples collected from the same habitat in different sites were used as replicates. STATISTICA Program (StatSoft, 1999) was used to carry out these analyses.

In order to check differences between macroinvertebrate compositions between habitats, a MRPP (Multi-response Permutation Procedures) was computed with PCORD Program (McCune & Mefford, 1999). This method is a nonparametric method for testing multivariate differences among pre-defined groups (R, Lc and Ld habitats), providing the statistic A and a p-value obtained by permutation (999 runs) as a result. Because its non-parametric condition this method is more appropriated than MANOVA in comparisons of data matrixes that involve species relative abundances including many zero values. To examine the meaning of the differences observed between sampled habitats, a Correspondence Analysis (CA) was performed to study the patterns of habitat distribution and the macroinvertebrates associated. This ordination technique is a multivariate approach that allows relating objects (sites) and descriptors (taxa) in a low-dimensional space. The measure used is the χ^2, appropriated for semiquantitative data. This method have been considered to produce better results than Principal Coordinate Analysis (PCA) with biological data, because matrices usually have numerous null values and χ^2 distance exclude double-zeros (Legendre & Legendre, 1998). Once the relationships between habitats and macroinvertebrates taxa were identified, a Bray-Curtis cluster was performed using a flexible method (β=-0.25) in order to check if macroinvertebrate communities were more similar between habitats that between adjacent riffle-pool sequences. Finally, to examine the most representative taxa in each habitat the

IndVal method (Dufrêne & Legendre, 1997) was applied. This procedure, independent of the CA results, examine characteristic taxa from a predefined group of objects (R, Lc and Ld) according to the presence and relative abundance of each taxa in each group independently of the others. Each taxa has associated an indicator value (IV-value) and a p-value obtained by Monte Carlo permutations (9999 runs). Only taxa with a high IV-value (over than 25) have been retained to understand patterns of macroinvertebrate distribution among habitats (Dufrêne & Legendre, 1997).

RESULTS

Physical, chemical and geomorphologic properties

Flowing water sites were characterized by a significant higher IHF, oxygen concentration and % of saturation than disconnected pools sites (Table 1). Conductivity, Temperature and pH had similar values between all samples. Discharge was highly variable between flowing water sites from 3.23 l/s to over than 6000 l/s. Obviously, because of the exclusive lentic conditions of disconnected pools, significant differences were found comparing discharge between flowing and intermittent reaches.

Table 1. Values of physical and chemical measured parameters. Kruskal-Wallis test between RLc and Ld are presented. ** indicates a significant differences at 0.05.

	River and site	IHF	pH	Oxygen-ppm	Oxygen-%	Temperature	Conductivity	Discharge (l/s)
R and Lc	Coyote	78	7.5	10.46	110.3	18.1	558	103.3
	Spanish	73	7.8	8.96	97.1	19.2	99	6270.95
	Cronan	81	7.4	9.96	99.7	15.4	118	454.4
	Lagunitas	83	7.8	10.6	104.6	14.6	182	1821.15
	Webb	78	7.6	10.0	96.3	13.5	340	40.95
	Saratoga	76	7.7	10.1	99.0	14.3	438	489.22
	Slate	74	7.8	8.1	89.9	20.4	108	3187.7
	Schneider	86	7.4	8.71	88.4	16.0	80	946.2
	Redwood	79	7.4	9.79	94.2	13.5	180	120.75
	Sausal Burns	62	7.8	3.85	42.8	21.7	499	3.23
Only Ld	Coyote-tributary	41	7.3	2.93	30.1	15.9	654	0
	Bear Gulch	50	7.5	6.41	67.8	17.0	578	0
	Dry	49	7.8	8.23	91.5	21.8	392	0
	Windsor site 1	50	7.9	1.47	15.5	16.6	328	0
	Windsor site 2	51	7.8	3.71	37.9	16.6	176	0
	Porter	49	7.8	2.39	24.0	15.1	262	0
	Brooks	58	7.8	5.23	59.2	22.7	331	0
	Wallace	64	7.8	6.18	62.8	16.8	208	0
	Maacama	58	7.8	5.04	57.9	22.3	351	0
Kruskal-Wallis test (χ2)		15.39	1.17	9.01	9.01	0.45	0.45	15.39
p-value		0.0001**	0.2788	0.0027**	0.0027**	0.4977	0.4977	0.0001**

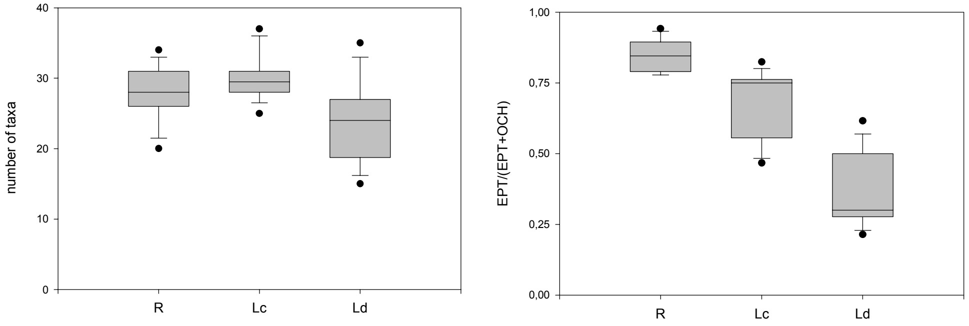


Figure 2. Box-Plots of number of taxa and EPT/(EPT+OCH) in R, Lc and Ld separately.

Changes in richness between habitats

Number of taxa is not significantly lower in Ld compared with R and Lc habitats independently (χ^2=4.34, p=0.1137) whereas significant differences are found in the EPT/(EPT+OCH) value (χ^2=20.50, p=0.000). Number of taxa presented a higher standard deviation between sampling sites in isolated pools than in riffles and connected pools (Figure 2). A decreasing number of Ephemeroptera, Plecoptera and Trichoptera taxa is observed from riffles to disconnected pools (Figure 2). Riffle samples have high values of EPT and few OCH taxa are present, whereas in connected pools a slightly higher OCH taxa or a fewer EPT were present. In disconnected pools, a high presence of OCH and few EPT taxa are noticed even though comparing with connected pools samples.

Changes in macroinvertebrate assemblages between habitats

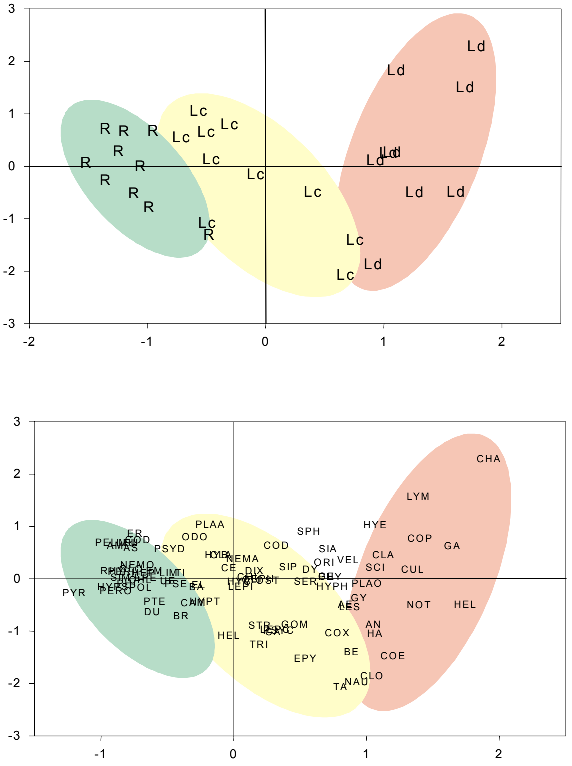
According to the MRPP results, macroinvertebrate assemblages are significantly different between all habitats (Table 2). A change of community structure from riffles to connected and disconnected pools is noticed in the first axis of the CA results (Figure 3) indicating that macroinvertebrates respond well to the differences present between habitats. The three habitats appear distinctively spread in the analysis with a clear gradient from riffles to disconnected pools. The first two axes explain together 28% of the sites variability. A longer dispersion of Ld sites in the second axis would indicate the high variability of macroinvertebrate composition found between samples from this habitat. Samples located in the top of the second axis have a distinct macroinvertebrate composition with high abundance of Chaoboridae, Lymnaeidae and Hydraenidae, whereas intermittent sites distributed through the bottom have a similar composition than some connected pools samples, sharing several Odonata (e.g. Lestidae, Calopterygidae or Coenagrionidae) and Heteroptera (e.g. Naucoridae, Corixidae and Belostomatidae). Lc samples appear to have a community between riffles and disconnected pools samples. Some Lc sites are more similar to disconnected pools with some taxa in common (e.g., Corixidae, Naucoridae, Hydrophilidae), whereas other are closer to riffles sharing taxa as Helicopsychidae, Odontoceridae or Hydroptilidae.

Table 2. Results of the MRPP analysis comparing macroinvertebrate community between R, Lc and Ld habitats.

	A	**p-value**
R and Ld	0,2713	0,0000114
Lc and Ld	0,1022	0,00004943
R and Lc	0,1182	0,00000614

In the cluster analysis of Figure 4, disconnected pools sites are segregated apart from riffles (R) and connected pools (Lc) habitats, which in turn, were clustered separately in all cases except for Coyote (gR) and Schneider (jLc) creeks where higher similarities between R and Lc are present. Riffles in Coyote Creek are more similar to connected pools habitat than to the rest of lotic samples. In contrast, connected pools habitat from Schneider Creek has a more riffle-community, and is grouped with the rest of Lc samples (Figure 4).

Riffles have 26 taxa with a high indicator value (IV-value) (Table 3). A high number of EPT taxa is characteristic from riffles. Stoneflies as Perlidae, Peltoperlidae and Perlodidae are restricted to R, and Nemouridae and Chloroperlidae are also present (with a high IV-value but non-significant) in connected pools. Several lotic caddisflies appear abundant and exclusive in riffles as Hydropsychidae, Rhyacophilidae, Glossosomatidae, Hydroptilidae, Brachycentridae and Uenoidae, whereas Limnephilidae is present in both habitats riffles and connected pools, but more significant in the last ones. Dipterans as Simuliidae, Tipulidae, Psychodidae and the non-insect taxa Hydracarina and Dugesiidae are indicator of riffles and absent in pools. Because of a gradient in the macroinvertebrate community is present between R and Ld through Lc (Figure 3), connected pools share taxa with riffles and disconnected pools and only 40.9% of indicator taxa are exclusive from this habitat.



Taxa's codes							
AE	Aeshnidae	DIX	Dixidae	HYPT	Hydroptilidae	PLAA	Planariidae
AM	Amelitidae	DU	Dugesiidae	LEPI	Lepidostomatidae	PLAO	Planorbidae
AN	Ancylidae	DY	Dytiscidae	LEPC	Leptoceridae	POL	Polycentropodidae
AS	Asellidae	EL	Elmidae	LEPH	Leptophlebiidae	PSE	Psephenidae
BA	Baetidae	EM	Empididae	LES	Lestidae	PSYD	Psychodidae
BE	Belostomatidae	EPE	Ephemerellidae	LEU	Leuctridae	PSYC	Psychomyiidae
BR	Brachycentridae	EPY	Ephydridae	LIM	Limnephilidae	PTE	Pteronarcyiidae
CA	Caenidae	ER	Erpobdellidae	LYM	Lymnaeidae	PYR	Pyralidae
CLA	Calamoceratidae	GA	Gammaridae	MU	Muscidae	RHY	Rhyacophilidae
CLO	Calopterygidae	GE	Gerridae	NAU	Naucoridae	SCI	Sciomyzidae
CAM	Cambaridae	GLO	Glossosomatidae	NEMA	Nematoda	SER	Sericostomatidae
CE	Ceratopogonidae	GOM	Gomphidae	NEMO	Nemouridae	SIA	Sialidae
CHA	Chaoboridae	GY	Gyrinidae	NOT	Notonectidae	SIM	Simuliidae
CHI	Chironomidae	HA	Haliplidae	ODO	Odontoceridae	SIP	Siphlonuridae
CHL	Chloroperlidae	HEL	Helicopsychidae	OLI	Oligochaeta	SPH	Sphaeridae
CLA	Cladocera	HEL	Helophoridae	ORI	Oribatidae	STR	Stratiomyidae
COE	Coenagrionidae	HEP	Heptageniidae	OST	Ostracoda	TA	Tabanidae
COP	Copepoda	HYC	Hydracarina	PEL	Peltoperlidae	TI	Tipulidae
COD	Cordulegasteridae	HYE	Hydraenidae	PERI	Perlidae	TRI	Tricorythidae
COX	Corixidae	HYB	Hydrobiidae	PERO	Perlodidae	UE	Uenoidae
COD	Corydalidae	HYPH	Hydrophilidae	PHI	Philopotamidae	VEL	Veliidae
CUL	Culicidae	HYPS	Hydropsychidae	PHY	Physidae		

	X1	**X2**	**X3**	**X4**
Eigenvalues	0.405	0.183	0.158	0.132
Cumulative % variance	19.6	28.4	36.0	42.4

Figure 3. CA graph of sites and taxa using R, Lc and Ld habitats. Eigenvalues, percentage of explained variability and taxa's codes are shown in the bottom.

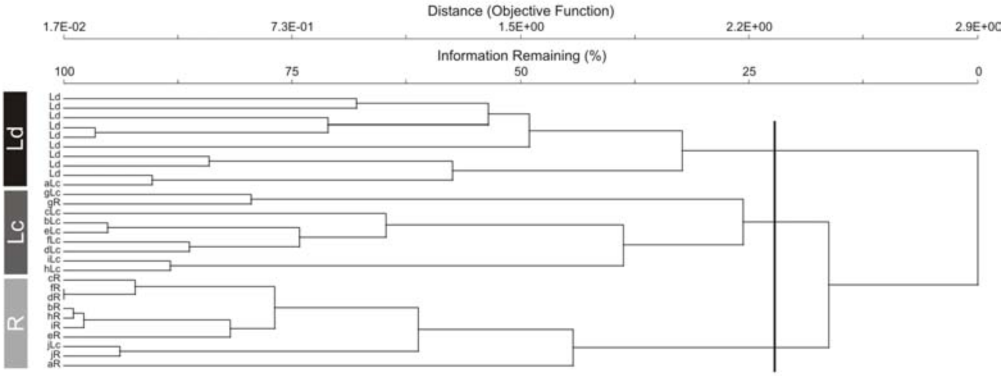


Figure 4. Bray-Curtis cluster with all data. R=riffles, Lc=connected pools; Ld=disconnected pools. Letters before R and Lc samples indicate the site and river plotted in Figure 1.

Table 3. Results of the IndVal method for R, Lc and Ld habitats. The indicator value (IV) and the p-value associated are shown.

R community

Species	IV-value	p-value
Hydropsychidae	96.4	0.0001
Simuliidae	93.2	0.0001
Rhyacophilidae	79.5	0.0001
Chloroperlidae	79.2	0.0001
Perlidae	77	0.0001
Tipulidae	77.2	0.0003
Heptageniidae	71.2	0.0012
Baetidae	64.3	0.0024
Ephemerellidae	68.6	0.003
Nemouridae	66.3	0.004
Philopotamidae	47.5	0.0045
Elmidae	64	0.0078
Empididae	62.3	0.0094
Polycentropodidae	47.5	0.0103
Dugesiidae	35.3	0.0251
Peltoperlidae	36.8	0.0311
Oligochaeta	54.4	0.2661
Hydracarina	53.6	0.3208
Glossosomatidae	44.9	0.0338
Hydroptilidae	44.8	0.1332
Psephenidae	39.3	0.1853
Brachycentridae	31.7	0.0973
Uenoidae	30.8	0.2069
Limnephilidae	28.3	0.7391
Psychodidae	26.2	0.1952
Perlodidae	25.5	0.187

Lc community

Species	IV-value	p-value
Calamoceratidae	40	0.0081
Ceratopogonidae	62.6	0.0116
Limnephilidae	56.3	0.0133
Gomphidae	36.2	0.0288
Leptophlebiidae	59.4	0.0454
Lepidostomatidae	55	0.0461
Elmidae	54.2	0.1537
Ostracoda	53.6	0.1095
Baetidae	53.6	0.1497
Gerridae	52.9	0.0833
Dytiscidae	52.5	0.1044
Empididae	43.2	0.2049
Nemouridae	39.5	0.324
Sialidae	36.2	0.2078
Ephemerellidae	34.8	0.6309
Heptageniidae	34.1	0.542
Chloroperlidae	34.1	0.6763
Nematoda	30.6	0.4342
Sericostomatidae	27.4	0.2517
Oribatidae	27	0.8311
Corduliidae	26.5	0.0842
Psephenidae	25.7	0.6808

Ld community

Species	IV-value	p-value
Copepoda	64.8	0.0001
Planorbidae	78.8	0.0002
Culicidae	71.7	0.0002
Gammaridae	55.6	0.0009
Gerridae	72.5	0.0012
Veliidae	47.5	0.0029
Physidae	69.8	0.004
Oribatidae	63.1	0.0043
Cladocera	45.4	0.0128
Lymnaeidae	33.3	0.0223
Gyrinidae	40	0.0225
Hydraenidae	40	0.025
Dystiscidae	60.1	0.0334
Sialidae	49	0.0361
Oligochaeta	52.1	0.4418
Leptophlebiidae	45.7	0.776
Dixidae	40.9	0.4475
Ostracoda	40.4	0.7215
Hydrophilidae	34.2	0.1263
Corixidae	28.9	0.3482
Haliplidae	26.2	0.1038

Some Ephemeroptera, Plecoptera and Trichoptera highly significant in riffles are also present in connected pools, as Heptageniidae, Baetidae, Ephemerellidae, Nemouridae and Chloroperlidae. The caddisfly Limnephilidae is also evenly distributed in lotic and adjacent lentic habitats, being more abundant in the last one. Although connected pools have some characteristic Coleoptera as Dytiscidae, others as Elmidae and Psephenidae are also present in riffles. Several exclusive taxa characterize connected pools, as the woody-cased caddisflies Lepidostomatidae and Calamoceratidae and two families of Odonata (Gomphidae and Corduliidae) which are typical from Lc but not from Ld. Other taxa characteristic from connected pools are also present in the disconnected ones, as Leptophlebiidae and Sialidae, found in both habitats but more significantly present in Lc than Ld. On the other hand, Gerridae and Dytiscidae are more representative from disconnected pools, although they are also present in Lc. Only Oligochaeta appear evenly distributed in riffles and disconnected pools. Although both habitats have many exclusive taxa, disconnected pools present a higher percentage of exclusivity (71.4%) than riffles (61.5%), indicating that connected pools are more similar to riffles than to disconnected pools. Heteroptera are highly significant in disconnected pools, with Gerridae, Veliidae and Corixidae as the most representative families. Gyrinidae, Haliplidae, Hydraenidae and Dytiscidae are also characteristic from Ld, jointly with three Mollusca families (Planorbidae, Physidae and Lymnaeidae). Crustaceans also are typical from this habitat, with Copepoda, Cladocera and Ostracoda as highly significant taxa.

DISCUSSION

Is the community in isolated pools impoverished?

Patterns in macroinvertebrate structure differ between riffles, adjacent pools and isolated pools but overall, no differences in richness between each independent habitat are observed. Previous studies reported similar number of taxa between riffles and adjacent pools (e.g., Scullion *et al.*, 1982; Logan & Brooker, 1983) what would agree with our results. Numerous controversies are found in the literature about the richness in riffles and pools. Boulton & Lake (1992) studying two intermittent rivers in Australia found in global a higher richness in pools than in riffles. Similarly, in a more arid area of North America, McCulloch (1986) found a higher number of taxa in pools than in riffles. On the other hand, Carter & Fend (2001) in a California river system found more taxa in riffles in low-gradient reaches but similar in high-gradient ones. Our study include a high variety of river typology in the riffle-pool samples (permanent and temporary sites in summer located in headwaters and midstream reaches) that could explain that in global, riffles and pools have a similar number of taxa. However, several problems should be present when number of taxa in riffles and pools are compared, because methodologies, sampling periods and taxonomic resolution used are different in most of studies (Logan & Brooker, 1983).

The habitat fragmentation in intermittent sites respect permanent ones does not imply a lower richness in isolated pools. Consequently, similar number of taxa would indicate that isolated pools operate as islands (*sensu* McArthur & Wilson, 1967) with organisms with high colonization and low extinction rates (Lawton, 2000). In fact, organisms found exclusively in these environments, as most of Coleoptera and Heteroptera, have been recognized to have these biological traits (Williams, 1987). However, Williams (1987) in a study of a temporary pond in Canada indicates that richness in temporary pools changes along the year, with maximum value in spring time. Consequently, the time when sampling was performed (spring) could affect the richness in isolated pools.

A higher variation in taxonomical composition is observed in isolated pools respect riffles and adjacent pools sites. Richness and biodiversity in streams have been strongly associated to disturbance and stability (Resh *et al.*, 1988; Vinson & Hawkins, 1998). According to the third Thienemann's principle (1954) richness is related to the length in which site has remained stable. Because disconnected pools are consequence of discharge disturbance in the beginning of a drought period (Lake, 2000), as far as the isolated pool have been disconnected to riffles, more stable should be and more taxa should hold (Thienemann, 1954; Williams, 1987). However, other factors have been recognised to influence richness in isolated pools. Schneider & Frost (1996) in a experimental study in Wisconsin found that the effect of predation and competition in temporary ponds is related to the habitat duration. Consequently, it is likely that a mix of factors (duration of isolated pools from permanent sites and predation, and even pool size) contribute to the high variability of richness in intermittent sites. Moreover, this explains the variability found in our data because some pools may be recently disconnected and other were since many weeks.

Are macroinvertebrates restricted to a specific macrohabitat?

All studies comparing riffles and pool habitats found a different macroinvertebrate community in each habitat (e.g., Logan & Brooker, 1983). However, the number of exclusive taxa for each habitat is variable. Armitage *et al.* (1974) found more unique taxa in pools than in riffles, whereas Scullion *et al.* (1982) demonstrated the opposite pattern. We found a higher exclusivity number of taxa in riffles than in pools, but lower than in isolated pools. The macroinvertebrate taxa indicator from riffles and pools agree with the one found in other studies (e.g., see Rabeni & Minshall, 1977; Armitage *et al.*, 1974; Scullion *et al.*, 1982;

McCulloch, 1986; Malmqvist *et al.*, 1993) although slightly differences in some taxa are found. Overall, in our study and elsewhere, riffles hold a numerous EPT fauna (Scullion *et al.*, 1982) whereas in pools OCH taxa are significant (Scullion et la., 1982; Logan & Brooker, 1983; McCulloch, 1986). However, some beetles are found in riffles, as Elmidae (considered to have lotic habitat requirements —Tachet *et al.*, 2000), and some ephemeropterans and plecopterans inhabit adjacent pools, as Leptophlebiidae (an indicator family in pools —Armitage *et al.*, 1974).

Isolated pools present a long list of restricted fauna with few similarities with riffles. This habitat is highly associated to OCH, Crustacea and Mollusca. Most of Mollusca have been recorded to pools (Logan & Brooker, 1983), but because their biological traits (long-lived organisms and slow dispersion) they have been rarely collected in intermittent sites (Brown & Brussock, 1991), except for Physidae recorded in some temporary pools (Williams, 1987). In our study, Mollusca is highly an indicator of isolated pools. Two causes could explain these observations. Mediterranean areas are characterized by high variability in hydrology between years (McElravy *et al.*, 1989), and evidences exist that macroinvertebrates are affected by the discharge and rainfall conditions of the previous year (Feminella, 1996). Consequently, intermittent sites during sampling period might be permanent in the year before, allowing the presence and survival of several mollusks. However, whatever the temporary condition in previous years, some Mollusca taxa could survive the last dry period creating a protective layer of dried mucous (Eckblad,1973), whereas other may have some life cycles adaptations beeing able to reproduce before the pool dries up (Brown, 1982). Crustaceans as Copepoda, Cladocera and Ostracoda, are significant indicators of isolated pools in our study and elsewhere. For instance, Williams (1987) in a comparative study in temporary pools in four distant regions found a highly convergent crustacean fauna.

Significant differences have been found between all sampled habitats in macroinvertebrate structure. However, high convergences have been noticed in indicator taxa between riffles and adjacent pools. Riffles and pools at the same site are more different that all sampled riffles or pools separately. Different arguments are found in literature about this phenomenon. Our results are similar to the ones found by McCulloch (1986) in two Texas streams. Similarly, Angradi (1996) in a study of three Appalachian streams comparing several microhabitats found strongest differences between habitats than between streams. However, in a study including several data from UK Rivers and streams, Logan & Brooker (1983) found the contrary. Angradi (1996) suggest that the scale of study is important to get one or another conclusion. In that sense, in a comparative study between riffles and pools in several mediterranean areas in the world, Bonada *et al.* (Chapter 3) found that, using common taxa, differences between regions were more important than differences between habitats in SWAustralia and South Africa, what is attributed to different local and historical processes acting in both areas.

Are connected pools an intermediate habitat?

Because of discrete habitats do not have a discrete taxa (Rabeni *et al.*, 2002), different degrees of similarity can be established between macrohabitats. When a drought is coming, riffles dry up quicker than pools (Boulton & Lake, 1990; Stanley *et al.*, 1997) and thereby, significant distances in macroinvertebrate structure should be present between riffles and isolated pools. In our study, nine families are indicator taxa from riffles and adjacent pools, whereas isolated pools only share four taxa with connected pools and one with riffles. Consequently, a gradient of flow conditions from riffles to isolated pools is shown by macroinvertebrate community. The CA analysis exhibit that some connected pools samples are close to riffles whereas some isolated pools samples are similar to connected pools in macroinvertebrate structure. As we have suggested previously, the high standard deviation of richness in isolated pools samples could be a consequence of the timing that these pools have been disconnected to riffles. Macroinvertebrate structure shows that some isolated pools have similar composition than some connected pools, whereas others have more distinct taxa with lots of predators (e.g., surprisingly, Chaoboridae was very abundant in one of the samples) indicating that these isolated pools are older than the ones close to connected pools but with an intermittent condition. However, in the case that sites would be disconnected from riffles at the same time, they could hold different macroinvertebrate composition because different taxa could colonize these “islands” and different predators could regulate the food web allowing the presence of a variety of different taxa. Consequently, we suggest that the higher dissimilarity observed in macroinvertebrate assemblage from isolated pools samples could be explained by (1) different time of disconnection from the riffle, (2) different taxa that colonize the pool, (3) different prey selection by newly arrived predators. These isolated pools became controlled only by local events (Lake, 2000), whereas in flowing water sites local and longitudinal processes may influence macroinvertebrate structures in riffles and pools.

Evidences exist about invertebrates moving away from riffles before they start to dry up (e.g., Delucchi, 1989). Several paths have been suggested for the movement of macroinvertebrates under a drought: upstream, downstream, hyporheic zone and to the laterals in banks or non-drying pools (Williams, 1981). We found that isolated pools could be refuges for some tolerant-lentic and long-lived fauna as Mollusca, but not for flow-preference invertebrates because low convergence in indicator taxa between riffles and isolate pools has been observed. Consequently, under a drought lotic macroinvertebrates can move to the next upstream riffles (Delucchi, 1989) but as drying bed moves towards, emergence is required to survive. In that sense, Brown & Brussock (1991) comparing riffles and pools in an intermittent river in Arkansas pointed out that riffle taxa displayed a life-cycle adaptation to avoid drought instead of an active migration to pools.

In summary, our results suggest that macrohabitats act as filters to enable the presence, absence and abundance of specific taxa (Poff, 1997). A gradient of flow conditions (from R to Ld) is congruent with a gradient of macroinvertebrate assemblages, but not in number of taxa. Abiotic and biotic factors acting at local or broad scale could be the responsible of these changes in biota. Low convergences between riffles and isolated pools in dominant taxa would suggest that isolated pools are not a refugee of lotic families under a drought, although it is likely that they could hold more tolerant-lentic taxa. Consequently, river macroinvertebrates in mediterranean areas are highly flexible under environmental conditions as a result of the climate, suggesting that despite of natural disturbances (floods and droughts) a high richness is present under different river and habitat conditions.

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Chapter 5

SPATIAL AND TEMPORAL HETEROGENEITY, MACROINVERTEBRATE RICHNESS AND SPECIES TRAITS IN A TEMPORARY MEDITERRANEAN RIVER SYSTEM: relationships with the River Habitat Template.

INTRODUCTION

Natural ecosystems are highly heterogeneous in space and time (Kolasa & Rollo, 1991; Stewart *et al.*, 2000). The heterogeneity concept has implicit the relationship between spatial and temporal variation in environmental constrains and the responses by organisms to them (Milne, 1991). Numerous studies are focused on looking for the biological implications of these constrains in terms of processes and mechanisms (Palmer *et al.* 1995, 1997; Townsend *et al.*, 1997). However, ecologists have generally consider temporal and spatial heterogeneity separately (see Shachak & Brand, 1991), and in that sense, Resh & Rosenberg (1989) incise in the need to analyze together both heterogeneities in aquatic processes, as they occur in nature at the same time.

Several factors are responsible to provide spatial and temporal heterogeneity in nature. Abiotic factors alone or induced by organisms (Picket *et al.*, 2000) have been reported as the main causes to them. Human and natural disturbances are also important sources of heterogeneity in ecosystems, because they alter the structure of environment and the distribution of organisms (Whiter & Harrod, 1997), although sometimes, human disturbance induces environmental homogeneity (Wiens, 2000). Different agents generate disturbance in ecosystems (see Wiens, 2000) determining the structure of aquatic communities (Resh *et al.*, 1988; Fisher & Grimm, 1991; Poff, 1992; Townsend *et al.*, 1997; Lake, 2000). In mediterranean areas, the climate itself is considered a natural predictable disturbance, altering the discharge regimes along and between years (McElravy *et al.*, 1989; Gasith & Resh, 1999). Floods and droughts are frequent in mediterranean ecosystems in different seasons (Molina *et al.*, 1994) displaying a high temporal heterogeneity. Both have been considered as the more important natural disturbances and their contribution to the stream patchiness induce a relevant spatial heterogeneity destroying and generating habitats (Lake, 2000). Although not all events causing heterogeneity are predictable (Pickett *et al.*, 2000), seasonal or annual heterogeneity in discharge in mediterranean rivers seems to be (Gasith & Resh, 1999), and evolutionary pressures have developed plant and animal communities highly adapted to it (di Castri, 1981; Stamou, 1998).

Temporary systems are well known for their variability in structure and invertebrate composition (Wiggins *et al.*, 1980; Williams, 1987), and they are present almost everywhere in the world (see Williams, 1987; Williams, 1996). Depending on the degree of temporality, rivers and streams can be classified as: permanent (flowing waters), intermittent (isolated pools) and ephemeral (dried stream beds) (see glossary at the end of this Chapter). These conditions can differ interannually (Feminella, 1996), and therefore interfere in the community composition of the following year. In mediterranean rivers this phenomena is very important, and it has been strongly associated with climatic features (McElravy *et al.*, 1989; Gasith & Resh, 1999). Moreover, the classification of mediterranean rivers in permanent, intermittent and ephemeral includes a temporal axis because the annual change of climatic conditions may imply a permanent condition from autumn to spring and permanent, intermittent or ephemeral reaches in summer in the same river (Gasith & Resh, 1999). The relationship between habitat and permanence have been poorly studied, although several studies incise in the change of habitat along time as the river is drying up (Boulton & Lake, 1992a; Williams, 1996) with riffles more affected than pools (Boulton & Lake, 1990; Stanley *et al.*, 1997). This habitat reduction during a dry season can be more or less important depending on the river characteristics (Lake, 2000), but in all cases macroinvertebrate community can be affected. On the other hand, flow patterns have also been considered heterogeneous in space and time (Poff & Ward, 1990; Palmer & Poff, 1997; Poff *et al.*, 1997). The attempts to quantify permanence in temporary systems have related macroinvertebrate community and structure to flow patterns (Feminella, 1996). The responses of macroinvertebrate communities to permanence have been studied by several authors, reporting slightly differences in faunal composition between permanent and intermittent sites with a high overlap of assemblages (Boulton & Suter, 1986; Delucchi, 1988; Delucchi & Peckarsky, 1989; Boulton & Lake, 1992a; Feminella, 1996; Williams, 1996; del Rosario & Resh, 2000). Different levels of responses have been analyzed but most of them are focused on taxonomical richness and composition. Williams (1991, 1996) emphasize the need to perform studies looking at the different species traits in temporary streams to know the adaptation of macroinvertebrate to these fluctuating and constrained environments.

The effects of spatial and temporal heterogeneity on organism's responses create patterns that are scale-dependent (Menge & Olson, 1990; Allen & Hoekstra, 1991; Poff, 1992; Holt, 1993), as different evolutionary forces act at each scale (Levin, 1992). In stream ecology, spatial heterogeneity has been referred to basins, rivers, reach, macrohabitat or microhabitat; and the temporal one to day, season, year and multiyear approaches (for examples see Resh & Rosenberg, 1989). Habitat studies have been numerous in ecology (see McCoy & Bell, 1991), and in stream ecology its static (composition) or dynamic (flow) properties and their relation with organisms have been presented in numerous studies (e.g., Poff & Ward, 1989; Palmer *et al.*, 1995; 1996; Biggs *et al.*, 1998).

The Habitat Template Theory (Southwood, 1977, 1988) has been underlying to understand the effect of the habitat heterogeneity on the macroinvertebrate responses and adaptations. This approach is based on the idea that habitat is a frame where the evolution occurs giving characteristic life history strategies to organisms and providing a community organization at different scales of perception (Townsend & Hildrew, 1994). In the contrary hypothesis, historic and phylogenetic features would constrain specific traits, independently of habitat (Gould & Lewontin, 1979). The relationship between habitat and their matched species traits has been studied in aquatic ecosystems with more emphasis in the last decade (Resh *et al.*, 1994; Townsend & Hildrew, 1994; Persat *et al.*, 1994; Poff & Allan, 1995; Statzner *et al.*, 1997; Townsend *et al.*, 1997; Poff, 1997; Statzner *et al.*, 2001), and recent studies shown that even in distant regions, species traits converge in the same habitat (Lamoroux *et al.*, 2002). The application of the Habitat Templet Theory to aquatic ecosystems was promoted by Townsend & Hildrew (1994) in the River Habitat Templet, where different traits were established in a two-dimensional space (spatial and temporal heterogeneities). Traditionally these two dimensions have been associated with disturbance (Hildrew & Townsend, 1987; Poff & Ward, 1990), and stable environments seem to favour specialist species, whereas in unstable conditions generalist strategies are common (Southwood *et al.*, 1974; Southwood, 1988; Poff

& Allan, 1995). The level of favourableness for organisms in a habitat is variable along time and space, showing different heterogeneous patterns (Southwood, 1977). Consequently, a quantification of the habitat including spatial and temporal aspects is crucial to understand the relations of organisms with environment and the effect of heterogeneity.

Predictions made by the River Habitat Templet have been tested by several authors, and some different results have been found at different scales (Persat *et al.*, 1994; Usseglio-Polatera, 1994; Resh *et al.*, 1994), indicating that not all species traits for all species match with the same habitat because trade-offs among traits. To avoid that, several authors have suggested testing habitat-traits theories using groups of organisms with similar species traits (Statzner *et al.*, 1997). In that sense, Usseglio-Polatera (2000) grouped different macroinvertebrate taxa in groups and subgroups of organisms sharing the same category of ecological and biological traits. We have used the traits from these groups or subgroups to check for the relationship of the habitat templet and traits in a mediterranean and temporary river system.

Thereby, the aims of this study are: (1) to quantify the spatial heterogeneity in habitat composition at reach scale in a Mediterranean river network; (2) to examine how this spatial heterogeneity affects on the temporal heterogeneity in a seasonal scale; (3) to study the influence of the spatial and temporal changes on the macroinvertebrate assemblage and its species traits; and (4) to study changes between wet and dry season ocurring in these sites affected by spatial and temporal heterogeneity.

STUDY AREA

The study was carried out in the Mediterranean streams and brooks in the Sant Llorenç Natural Park area (Catalonia, NE Spain) (Figure 1). This area offers a unique opportunity to understand the change produced in the macroinvertebrate community structure between the dry and wet period in absence of heavy man disturbances, something difficult to find in areas colonized by man since 2000 years ago. In a previous paper data about water quality, macroinvertebrate feeding strategies and community structure was presented (Rieradevall *et al.*, in press).

Sant Llorenç del Munt Natural Park has been protected for 30 years. It is located north of the Barcelona metropolitan area (NE Spain) and extends on a surface area of 9630 Ha. The mountain ranges in which the park is located have a typical Mediterranean climate, with irregular and intense rains mostly falling winter but with some spring and autumn precipitation, while summer is normally a very dry period (see Figure 2). The park has a dominant karstic geology with highly permeable substrates and, therefore, surface flow in streams may cease in hours or days after the rains. However, some permanent streams exist, mostly linked to the presence of springs discharging from the karstic aquifer. Evergreen oak trees or white pines cover the park, except in the steepest areas or in places with rock outcrops. The protected studied area is situated between altitudes ranging from 280 to 1100 m and 20% of the studied reaches extended far beyond the limits of the park. The park is a quite popular area for hiking with several small tourist resorts and the number of visitants registered by the park service is close to 80,000 annually. The sampled streams belong to two main catchments that discharge to the Mediterranean Sea, the Besòs and Llobregat rivers, whose main channel and tributaries are well known from several previous studies (Prat *et al.*, 1999; 2000; 2001).

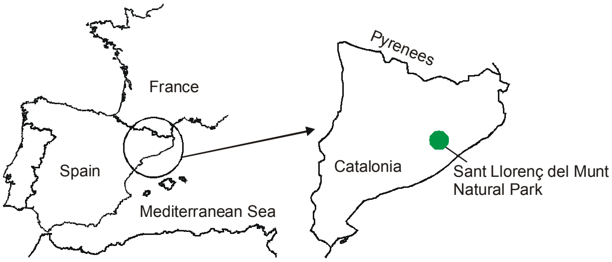
MATERIAL AND METHODS

Data collection

A total of 78 localities were visited in February (wet season) and August 1996 (dry period) and in each site the condition of the stream was recorded as permanent (>1 l/s), intermittent (only pools) or ephemeral (dry), according to Dietrich & Anderson (2000). However, because of the high ephemeral nature of the network, only 25 sites, that were permanent in winter, were sampled (Figure 1 a-b). In each site, the discharge was measured in winter and summer time using a flow meter and the section of the river channel. The structure of the habitat was recorded in wintertime estimating the percentage of gravel, cobbles or bedrock and the percentage of pools versus riffles in a 50 m reach.

Temperature, pH, conductivity and dissolved oxygen (mg/l and % of saturation) were measured "in situ" for each locality using portable equipment. Also, one liter of water was collected, kept cool and analyzed in the laboratory for calcium, potassium, chloride, sulphates, ammonia, nitrite, nitrate, phosphorus and suspended solids.

All available habitats were sampled for the macroinvertebrates using a circular net of 250 µm of mesh size, with "kicking" method with a similar time-effort in each sampling site. The samples were preserved with formalin and sorted and identified at family level. When it was possible, genus/species were obtained. For each taxon the relative abundance is used in data analysis.



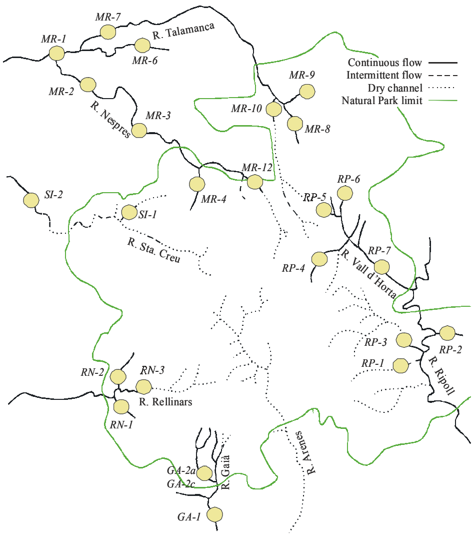


Figure 1a. Sampling area and sites with the channel status in the wet season (February 1996). Red circles indicates dried beds.

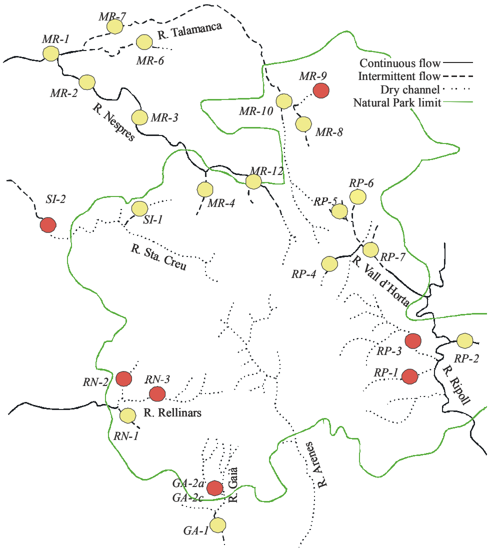


Figure 1b. Sampling area and sites with the channel status in the dry season (August1996). The black spots indicate the dry sites.

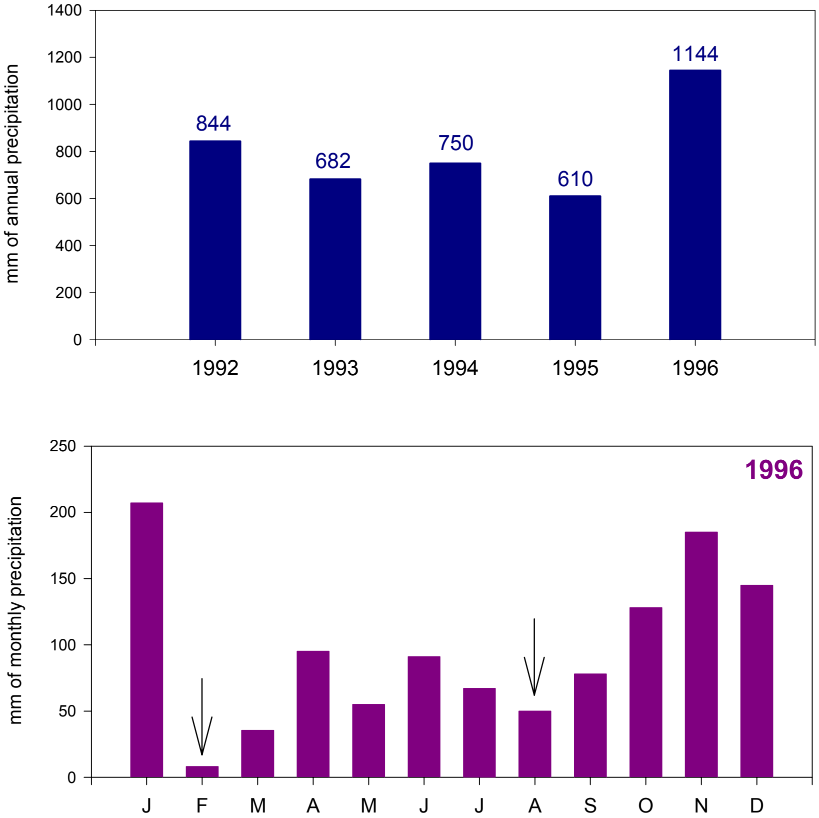


Figure 2. **a.** Annual precipitation between 1992 and 1996 recorded in the Park (Coll d'Estenalles area). Data from the "Servei de Parc Naturals de la Diputació de Barcelona".
b. Monthly precipitation along 1996. Arrows indicate sampling seasons.

The study was carried out in a very wet year after several ones with medium annual rainfall (Figure 2a). Most of the rain in 1996 was recorded in January and autumn months, whereas spring time presented a medium to low levels of rainfall. Consequently, samples from wet (February) and dry (August) seasons were collected after a high and low precipitation period, respectively (Figure b).

Data analysis

Seasonal changes in macroinvertebrate assemblages

Seasonal changes were measured comparing winter (February) and summer (August) sampling periods using a Canonical Correspondence Analysis (CCA) with CANOCO program (ter Braak, 1998). All the physicochemical variables measured were standardized and log-transformed previously to the analysis. CCA analysis is a multivariate ordination technique based on eigenvalues, where the variation in community composition is explained by several ordination axes, linear combinations of environmental variables (Legendre & Legendre, 1998). The family was used to this analysis, as not all taxa were identified at genus or species level.

Heterogeneity, physical factors and temporality

The spatial heterogeneity has been analyzed measuring the physical structure using three factors: a) the percentage of conglomerate bedrock versus cobbles and gravel, b) the amount of flow in each site in winter and summer and c) the percentage of riffles and pools at the time of sampling (Annex 1).

To relate habitat (as substrate composition, velocity and flow) with temporality, we formulated the hypothesis that the stream should be less temporary in each of these circumstances: 1. Over large conglomerate bedrock (no infiltration) versus areas were gravel or cobbles dominate, 2. When large pools are more important than riffles (more water accumulated), 3. When a high flow is present in winter and 4. When permanent flow exists in summer. To quantify the spatial and seasonal heterogeneity according to these factors we estimated for each sampling point a reach permanence score (RPS), in a similar way as Feminella (1996) did in a temporary stream.

RPS calculation was done as follows (Annex 2). First, we ranked the 25 localities according to the importance of four attributes separately: (1) its percentage of bedrock; (2) the percentage of pools; (3) its relative winter flow (in respect to the maximum discharge in this period); and (4) its relative summer flow (in respect to the maximum summer discharge). As we had 25 stations, for each parameter, the first station with the highest percentage of this parameter will receive a maximum score of 25, the next 24… and lower values successively until the last station that will receive score of 1 for this parameter. For each parameter all percentages were grouped in classes (i.e., 0.1-9%, 10-19%…), and for flow . When several localities had the same percentage of one of the parameters the mean rank score of its ranks scores will be given to each of them. For example, if three stations have 90% of hard substrata and their rank is between number 24 and 22, a score of 23 was given to each of the three stations.

After the rank of sites, the four scores were added for each station and the final RPS was obtained which may vary between 100 and 4 (Table 1). In the first case, the score implies that the sampling point was arranged in the first position and is supposed to be the more permanent (mostly pools, over hard substrata and maximum flow recorded both in winter and summer). On the other hand, the last value (4) will signify that the sampling point was the last in all partial ranking (only riffles, over gravel or cobbles and with no flow or the smallest flow in both occasions), and therefore should be the more ephemeral.

Table 1. RPS Score and summer status of the channel for each site. The sites are divided into three groups (Permanent, Intermittent and Ephemeral) according to the k-means results. Only pools is referred to sites with disconnected pools in summer or with pools connected by ≤1l/s.

	FINAL SCORE (A+B+C+D)	**Summer status**	**CATEGORY**
MR2	84	Flow >1 l/s	PERMANENT
MR6	80	Only Pools	
RP2	77	Flow >1 l/s	
MR7	72.5	Flow >1 l/s	
RP7	69.5	Flow >1 l/s	
MR3	68.5	Flow >1 l/s	
MR12	66	Flow >1 l/s	
MR1	64.5	Only Pools	INTERMITTENT
MR8	64	Only Pools	
RN1	62	Flow >1 l/s	
RP4	61.5	Only Pools	
MR4	59	Only Pools	
GA1	57.5	Flow >1 l/s	
SI1	56.5	Only Pools	
RP6	52.5	Only Pools	
MR10	46.5	Only Pools	
RP5	40.5	Only Pools	
RN2	38.5	Dry	
GA2c	34.5	Dry	EPHEMERAL
SI2	31	Dry	
GA2a	31	Dry	
RN3	29.5	Dry	
MR9	16.5	Dry	
RP3	16.5	Dry	
RP1	16.5	Dry	

Macroinvertebrates and temporality

This ranking will give us the gradient of the stations according to its permanence (or ephemerally) measured by physical factors (the RPS value). To separate this gradient in three groups of sites according to their condition (permanent, intermittent or ephemeral) minimizing the error, a k-means clustering using 3 groups was performed with SPSS statistical package (SPSS, 1999). For each group of sites obtained, the error of classification (e.g., number of intermittent sites grouped in the permanent group) was calculated. The k-means method is a cluster technique where objects are separated in a pre-established number of groups, looking for higher similarities inside each groups and differences among groups (Legendre & Legendre, 1998).

Differences of macroinvertebrate richness between temporality conditions and richness were assessed using a Kruskal-Wallis non-parametric ANOVA test, as the richness values differed from normality. The STATISTICA Program was used to perform the analysis (Stat Soft, 1999).

The "4th Corner Method" (Legendre *et al.*, 1997) was used to check for differences in biological traits between temporality conditions. This statistical program uses a biological matrix (taxa *vs.* sites), a behavioral matrix (taxa *vs.* traits) and an environmental matrix (sites *vs.* environment or habitat) to create a new one that relates the different kind of habitats with the different traits. In our case, the biological matrix was February and August matrix transformed to presence/absence because requirements of the program; the environmental matrix was the pertinence of each locality to the three groups increasing in permanency, ephemerally and intermittency, according to the k-means groups; and the behavioral matrix was the value of the biological traits for each taxa. Correlations between traits and habitats were computed in the program. Two hypotheses are tested by program in these conditions:

H_0: All habitats are suitable for all individual species.
H_1: Individual species find optimal conditions in the sites where they are found.

The traits studied were classified into biological and ecological according to Usseglio-Polatera *et al.* (2000). For our study only the biological ones (more related to behavior) have been used. Information of biological traits of some taxa is not available in the paper of Usseglio-Polatera *et al.* (2000) and these were excluded from the analysis (e.g., Hydracarina, *Aquarius najas*). The biological traits used involve life cycle aspects (maximum size, life cycle duration, potential number of reproduction cycles per year, aquatic stages), resistance or resilience (dispersal, substrate relation, resistance form), physiology and morphology (respiration, locomotion) and feeding and reproduction behavior (reproduction, food and feeding habits). Their categories are listed in Annex 3, according to the ones in the Usseglio-Polatera's paper based in a "fuzzy coding" procedure from 0 (no affinity) to *n* (high affinity). In total 63 categories have been used and they have been associated with the groups from RPS score in the same rank proposed by Usseglio-Polatera *et al.* (2000). To perform the traits matrix, each taxa was checked for the group or subgroup in the Usseglio-Polatera's list (Annex 4), and for each taxa and trait categories were selected according to the frequency of distribution. To simplify the data analysis and to avoid trade-offs, the category with a maximum affinity was selected for each group or subgroup (Annex 5).

The result of the program is a matrix of r-values and p-values associated for each biological trait used and each habitat. The r-value indicates a correlation between the habitat (permanent-intermittent-ephemeral) and the modality of the species trait (1-2-3-4-..., depending on the trait). Thus, a positive and significant r-value for one habitat and trait would indicate that the habitat has a modality of the trait corresponding to a high number, meanwhile a negative value would show the presence of a low modality of the trait (according to the Annex 3).

RESULTS

Seasonal changes and its effects on macroinvertebrates

Because of climate and geology of the sampled area, several streams dry up in summer every year, with or without pools remaining in them. While in very dry years flow may cease in all the streams, in wet years part of them maintain permanent flow. The year 1996 was a relatively wet year (Figure 2). The flow condition of the drainage network of Sant Llorenç Natural Park for both periods of time can be seen in Figures 1a (winter) and 1b (summer). Three situations observed during each sampling period are illustrated in each figure: 1) Flowing water (from 1 to 600 l/s)-(continuous line), 2) River courses with pools but without surface flow (dashed lines) and 3) Dry watercourses (dotted line). That is, permanent, intermittent and ephemeral streams. In winter, 63% of the total length network had a continuous flow, while in summer only a 26%. The rest of river length was intermittent (only pools) or ephemeral (dry). The main streams with permanent flow in summer were outside or in the limit of the park area, downstream of permanent springs with a karstic origin. Although 1996 was a wet year, 8 of the 25 sites sampled in February were totally dried up in summer.

As a change in the flow condition between the wet and the dry period was noticed, the influence of this seasonal heterogeneity on the macroinvertebrate community was studied using a CCA analysis with all the data. The results are presented in Figures 3 and 4. Chloride, sulphates, conductivity, ammonia, phosphate, nitrate and nitrite were very similar between all the sites, as the streams sampled are not affected by human influence. Thus, the results of the CCA indicated that these chemical parameters were not significantly important to explain the variability of the macroinvertebrate data and they were not considered in the analysis. On the other hand, temperature, calcium, potassium, oxygen, flow and pH were significantly different and were retained as parameters with significant changes between stations or in time. The two first axes of the CCA explained 68% of the total variability of the data.

This analysis shows the importance of annual seasonal change in the matching of the communities. The first axis explains 43% of the variance and is related to high temperatures and low oxygen and flow in the right side. Samples taken in August (high temperature and low flow) are grouped together in the positive area of the first axis and clearly separated from those of February (Figure 3). All taxa exclusive from winter are in the left part of Figure 4, as Nemouridae, Philopotamidae, Leuctridae, Athericidae, Chloroperlidae or Glossosomatide, and they can be considered as lotic taxa associated with low temperature and high flow. On the other hand, those present only in summer are lentic taxa, related to a higher temperature and no flow and are situated on the right, as most of the Coleoptera, Heteroptera and Odonata. Taxa as Baetidae, Chironomidae or Oligochaeta were located in the middle of the graph, and as they were present in both sampling periods, can be called as the core species suggested in Boulton & Lake (1992b).

The second axis, with 24.56% of the variance explained is related with the effects of water velocity and algae activity on the physicochemical characteristics and the community composition. In high flow conditions and low temperature, oxygen concentration and pH increased, while calcium carbonate precipitates. The riffle species from the lower part of Figure 4 are more related to these conditions than pool species (families on the upper part of Figure 4). The family Sphaeriidae is located in the upper part of the graph, and seems to be related with the calcium concentration that can be important for maintaining the shell.

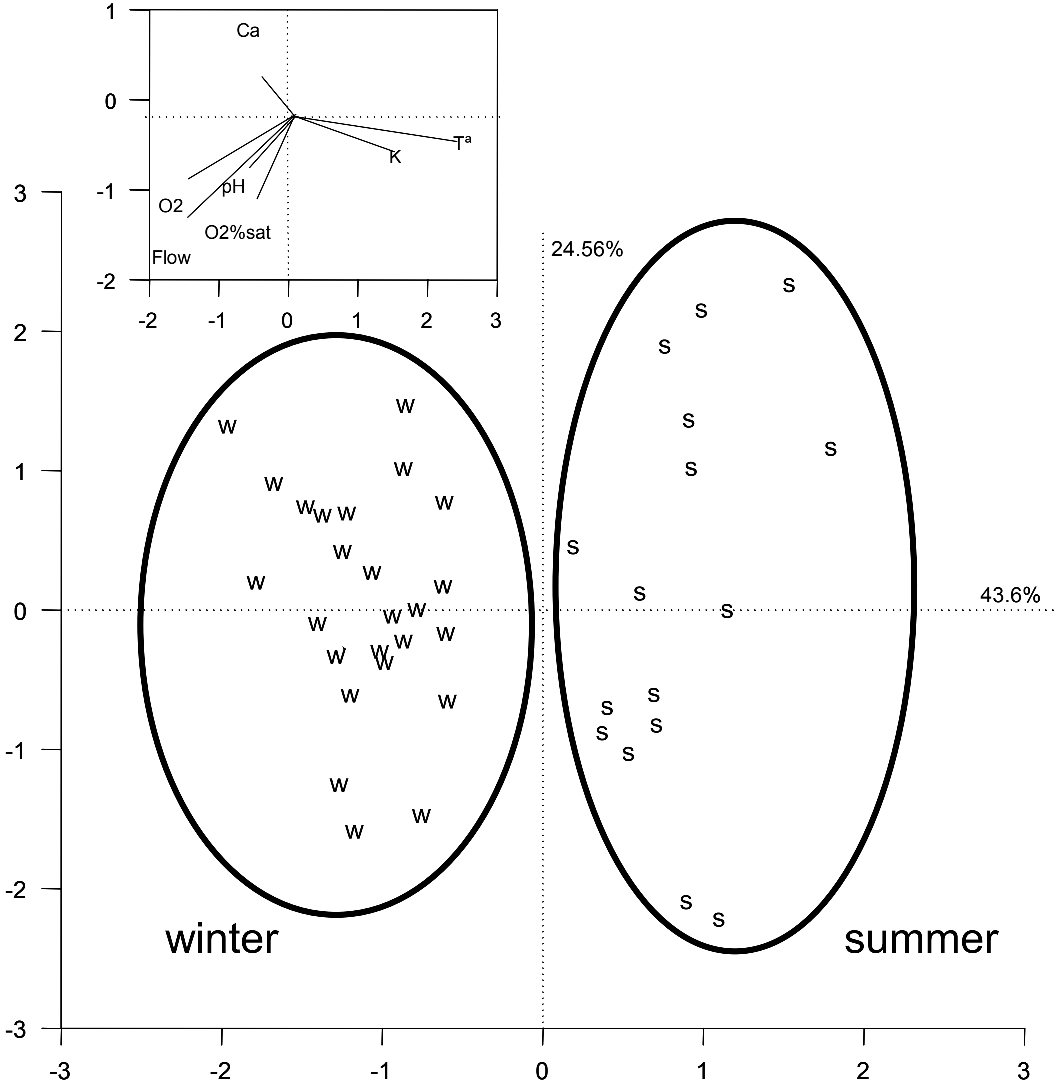
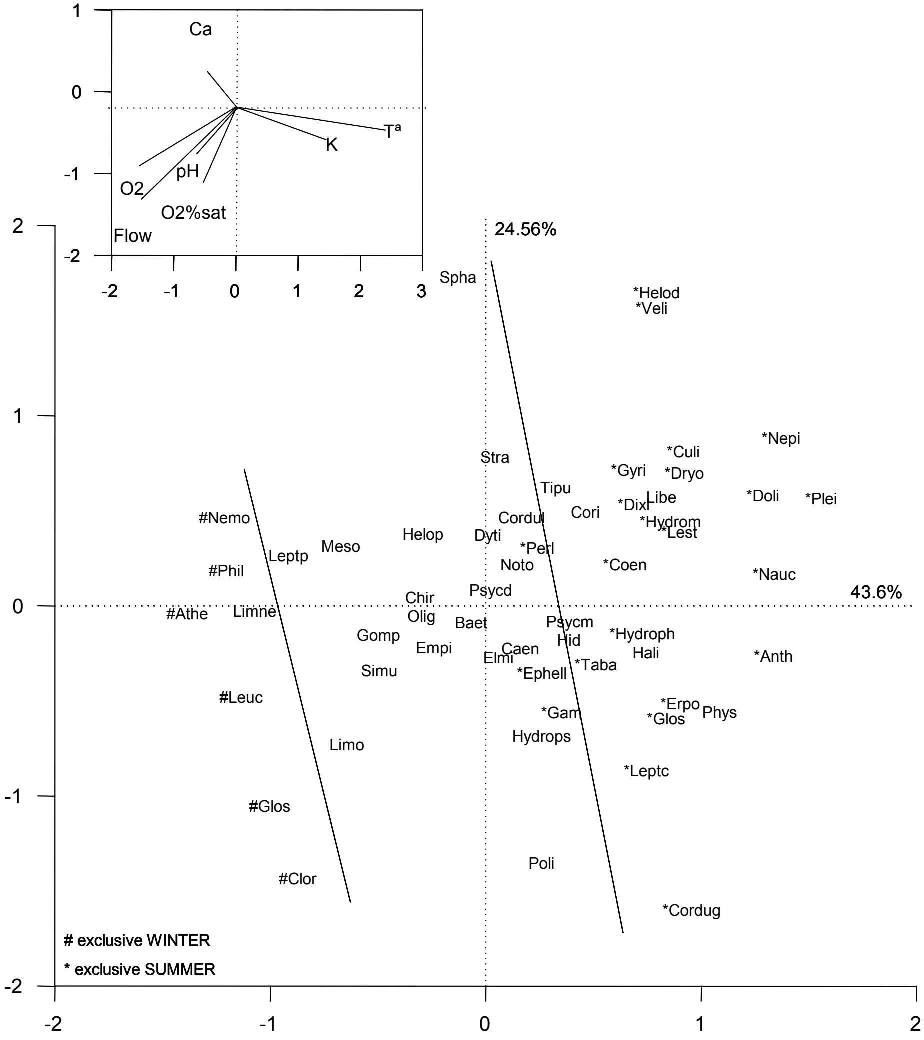


Figure 3. Results of the CCA analysis using February and August samples.



Taxa's codes:

Nemo=Nemouridae
Leuc=Leuctridae
Lept=Leptophlebiidae
Helop=Helophoridae
Baet=Baetidae
Ephell=Ephemerellidae
Noto=Notonectidae
Stra=Stratiomyiidae
Psycm=Psychomyiidae
Cordug=Cordulegasteridae
Hali=Haliplidae
Nauc=Naucoridae
Gyri=Gyrinidae
Libe=Libellulidae

Phil=Philopotamidae
Glos=Glossosomatidae
Meso=Mesoveliidae
Chir=Chironomidae
Poli=Polycentropodidae
Elmi=Elmidae
Perl=Perlidae
Spha=Sphaeriidae
Hid=Hydracarina
Glos=Glossosomatidae
Hydroph=Hydrophilidae
Doli=Dolichopodidae
Dixi=Dixidae
Dryo=Dryopidae

Athe=Athericidae
Clor=Chloroperlidae
Gomp=Gomphidae
Olig=Oligochaeta
Hydrops=Hydropsychidae
Caen=Caenidae
Dyti=Dytiscidae
Tipu=Tipulidae
Taba=Tabanidae
Erpo=Erpobdellidae
Coen=Coenarionidae
Plei=Pleidae
Hydrom=Hydrometridae
Culi=Culicidae

Limne=Limnephilidae
Limo=Limoniidae
Simu=Simuliidae
Empi=Empididae
Gam=Gammaridae
Psycd=Psychodidae
Cordul=Corduliidae
Cori=Corixidae
Leptc=Leptoceridae
Phys=Physidae
Anth=Anthomyidae
Nepi=Nepidae
Lest=Lestidae
Helo=Helodidae

Figure 4. Results of the CCA analysis. The families are plotted. The lines separate the families only present in winter (#cold taxa) from the ones in summer (*lentic taxa) and the core species (always present).

Spatial Heterogeneity and its relationship with temporal heterogeneity

Using the ranking method described above (RPS score), the sampling stations were arranged from the most permanent to the more ephemeral from the data provided in Annex 1. The rank ordination of the stations for each attribute is indicated in Annex 2 (percentage of hard habitat, percentage of pools and the relative flow in winter and the summer). The final RPS score (the sum of the four values for each sampling site) is in Table 1 with RPS scores ranging from 16.5 to 84. This is the physical gradient defined by this index, going from the more permanent station (MR2) to the more ephemeral one (RP1).

In Table 1 together with the physical gradient according to the RPS score, the observed condition of each site in the field (with flow higher than 1 l/s in summer, only pools in summer or dry) is presented. According to these results and in order to make easier further analysis and interpretations, the gradient has been separated in three categories or groups by the k-means clustering (permanent, intermittent and ephemeral). According to the analysis the first 7 sites are classified as permanent (with an error of bad classification of 14%); the next 11 as intermittent (with an error of 27%); and the last 7 sites as ephemeral (with an error of 0%).

Spatial and Temporal heterogeneity and macroinvertebrates

Figure 5 shows the number of winter families and summer families along the RPS gradient. The limit between permanent, intermittent and ephemeral stations are showed in the figure. There is a clear gap between the ephemeral and the other stations, with an increase of summer taxa in intermittent and permanent stations in summer and winter seasons. The maximum number of families has been found in a site that in summer has high percentage of pools and with flow between them (RP7). In permanent and intermittent sites, the number of families found in winter was higher than in summer. Summer season present a lower number of taxa although they enhance an increase of the total richness, with addition of an average of 8 new taxa. Although a change in richness is observed along the gradient, the Kruskal-Wallis non-parametric ANOVAs indicate that only in the ephemeral sites have significant lower values ($p<0.03$ for total, winter and summer). No-differences were found comparing permanent and intermittent richness, in summer ($p=0.473$), winter ($p=0.205$) or both periods ($p=0.628$).

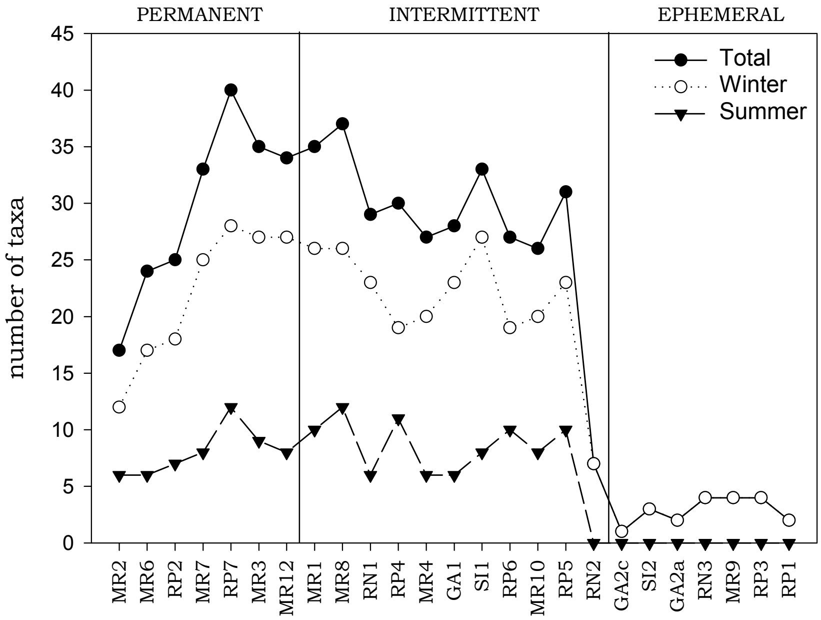


Figure 5. Variation of the number of taxa (total, winter exclusive and summer) along the RPS gradient from permanent to ephemeral reaches.

When EPT and OCH values are compared in separately in the wet and dry period (Figure 6), no differences between permanent and intermittent sites can be distinguish. Besides, ephemeral sites present a very low number of EPT and OCH fauna in winter respect intermittent and permanent conditions. Accordingly to the observed in Figure 3 and 4, differences from wet and dry period in the macroinvertebrates are based in a change from EPT dominant to OCH dominant.

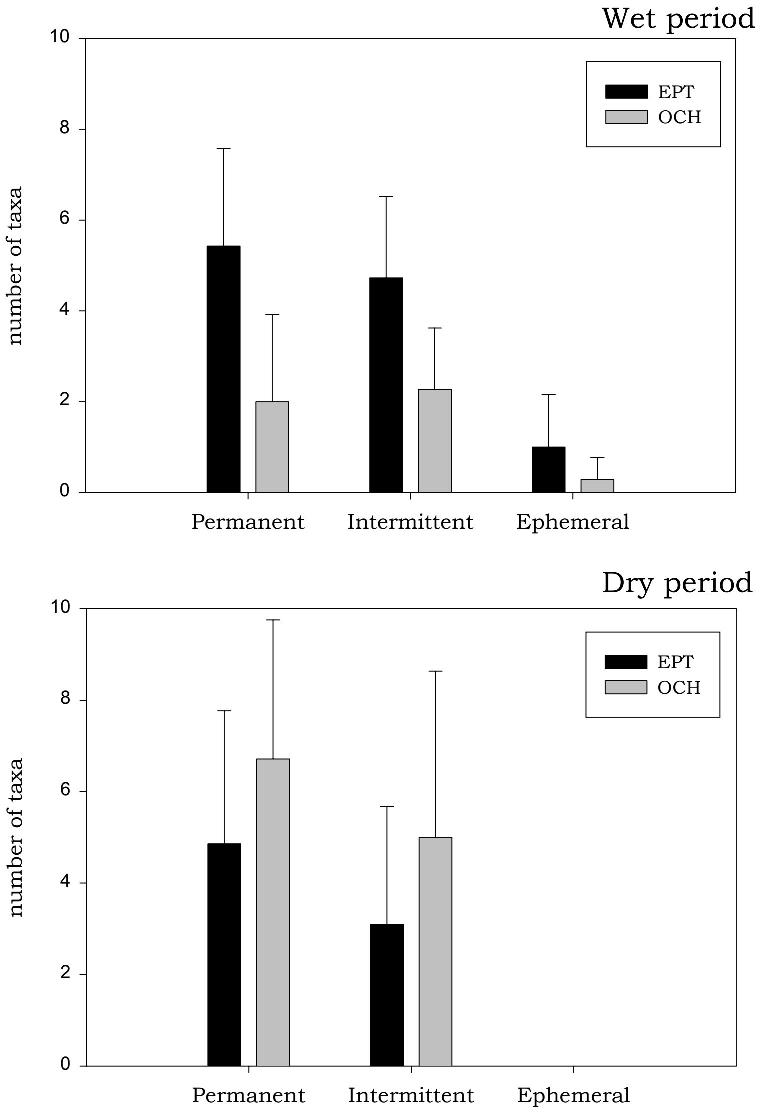


Figure 6. Mean and standard deviation of the EPT and OCH values for permanent, intermittent and ephemeral reaches in the wet and dry period.

Results from the 4th Corner Method show several significant patterns in between biological traits from permanent, intermittent and ephemeral streams (Table 2). A mix of behavior features seems to be present in permanent sites (as no significant traits are shown), while some specific ones are exclusive from intermittent and ephemeral situations, independently. However, "Maximal size", "Reproduction", "Resistance forms" and "Feeding habits" are not significant in any category, in contrast to "Life cycle duration", "Potential number of reproductions per year", "Aquatic stages", "Dispersal", "Respiration", "Locomotion and substrate relation" and "Food". In intermittent sites "Life cycle duration" is significantly over than 1 year with several reproductions per year, and its community is dominated by flying, swimmer or surface swimmer adults with aerial respiration and an active and by air dispersion. In contrast, ephemeral sites are dominated by larvae that breath by gills or tegument and are attached on the substrate. Their dispersion is by water and has short life cycle duration (lower than one year) and few reproductions per year. Food appears significant in ephemeral sites, with larvae feeding in fine sediment or detritus.

Table 2. Results of the 4th Corner Program, for each biological trait tested and flow category. The most significant traits are indicated with * ($p<0.05$) or ** ($p<0.01$).

	PERMANENT		**INTERMITTENT**		**EPHEMERAL**	
	r	p-value	r	p-value	r	p-value
Maximal size	0.036	0.192	-0.043	0.147	0.017	0.335
Life cycle duration	-0.01	0.389	0.066	**0.043***	-0.123	**0.0008****
Nº reproductions / year	-0.022	0.288	0.053	**0.094***	-0.069	**0.046***
Aquatic stages	-0.011	0.274	0.072	**0.0024****	-0.113	**0.001****
Reproduction	0.004	0.49	-0.004	0.442	-0.0001	0.509
Dispersal	-0.028	0.218	0.085	**0.011***	-0.128	**0.0005****
Resistance form	0	1	0	1	0	1
Respiration	-0.036	0.156	0.082	**0.015***	-0.103	**0.0045****
Locomotion and substrate relation	0.002	0.496	-0.054	**0.087***	0.1157	**0.001****
Food	0.018	0.317	0.032	0.188	-0.113	**0.001****
Feeding habits	0.004	0.466	0.004	0.441	-0.021	0.294

DISCUSSION

Classification of heterogeneous environment is the key to understand organisms' patterns and responses (McIntosh, 1985). Heterogeneity itself provides the presence of environmental gradients spatially continuous or discontinuous (Keddy, 1991). The spatial heterogeneity in our mediterranean system has been directly ranked in a gradient of sites to test 4 different hypotheses. The gradient of sites obtained by habitat categorization, provide a gradient of temporality (permanent, intermittent and ephemeral sites). Spatial and temporal heterogeneities can have implications on macroinvertebrates independently but the interaction between them can determine some patterns and processes (Keddy, 1991). Relationships between both heterogeneities are not easy to study because of their complexity and several methodological constraints (Kolasa & Rollo, 1991). Consequently, few studies analyze both heterogeneities (Resh & Rosenberg, 1989; Watling & Press, 2000; Wiens, 2000), and even less report the interaction between them, although Wiens (2000) suggested that variation in time often creates patterns in spatial heterogeneity. In that sense, using a simple quantitative index, we are showing how temporal heterogeneity (i.e., if the river will be permanent, intermittent or ephemeral in summer) is affected by spatial heterogeneity (i.e., the composition of habitat in terms of substrate and flow).

This easy method to quantify the spatial heterogeneity and its relationship with temporal changes should be carefully applied in other areas in the world, as rivers characteristics and climatic features are different. For example, although the hypothesis related to habitat characteristics (riffles vs. pools and gravels and cobbles vs. bedrock) can be applied in other climates, the % of winter and summer flow hypothesis can differ. In mediterranean rivers, base flow is strongly related with precipitation, evapotranspiration and ground water level (Vidal-Abarca, 1990; Camarassa & Segura, 2001). Thereby, in mediterranean climate low discharge in winter is more likely to imply temporality in summer than high discharge, than in other areas where summer flow is significant.

Comparisons between wet and dry seasons

Changes of macroinvertebrate assemblages among seasons have been reported by several authors (Boulton & Lake, 1992b; Boulton & Lake, 1992a; Graça *et al.*, 1989). Boulton & Lake (1992b) also suggest a change of species related to the change in habitat structure. In our case, winter exclusive species as some Plecoptera (Nemouridae, Leuctridae, Chloroperlidae) or Trichoptera (Philopotamidae) are related to riffle conditions in wintertime and are called "main flow species". They disappear with a decreasing of flow through spring and summer. These taxa are substituted by lentic species, mostly OCH species (Odonata, Coleoptera and Heteroptera) able to survive in pools or dominant lentic habitats. An overlap of macroinvertebrates between winter and summer season is also present, with several families present in both seasons and most of sites, as Chironomidae, Oligochaeta, Caenidae, Baetidae, called core species by Boulton & Lake (1992b). Core species have an even distribution in space and time, what could be related with their broad niche (Vandermeer, 1972), and in fact, these taxa have been recorded in almost all lotic stream studies. On the other hand, main flow species and tolerant lentic ones are restricted to specific habitats because, and as a consequence the show a narrower distribution.

Macroinvertebrate comparisons between permanent, intermittent and ephemeral sites

Several authors with contrasting results have compared richness in permanent and temporary sites. In part, the disparity of results is because of the different concept of temporary sites in different papers, as some consider them as sites that dry up completely in summer, whereas others refer to rivers that have isolated pools in dry period. We have considered that temporary sites included both, and we have separated them in intermittent and ephemeral localities (see Glossary at the end of this Chapter). For instance, Wrigth *et al.* (1984) or del Rosario & Resh (2000) found lower richness in temporary than permanent sites, whereas Legier & Talin (1973), Boulton & Suter (1986) and Miller & Golladay (1996) and report similar richness. Dieterich & Anderson (2000) found a 20% higher richness in the pools of two temporary Oregon streams than in a permanent stream, and a lower diversity in ephemeral sites. In our studied rivers, intermittent and permanent sites have similar taxonomical richness, but higher than ephemeral sites. The colonization of a new habitat implies a high development and abundance of some highly resilient species (Dell *et al.*, 1986; Townsend & Hildrew, 1994), and therefore a low diversity should be expected in ephemeral sites. In contrast, in the permanent and intermittent reaches, where water remains during a long period of time, we have found an increase of diversity. In that way, the dry season length have been recognized as one important factor to determine diversity in these streams, postulating that the longer the dry season is, lower is the diversity (Williams & Hynes, 1976; Abell, 1984; Williams, 1996). On the other hand, the high interannual variability in precipitation and stream discharges in mediterranean rivers (McElravy *et al.*, 1989) may imply an interannual variability in the conditions of temporality of one site (del Rosario & Resh, 2000). The low taxonomical richness in our ephemeral sites suggest a ephemeral condition the year before the study, and the high difference in richness from permanent sites, would suggest a slow recovery from the last dry period (5-6 months ago), which is in agreement with other authors (Boulton & Lake, 1992b; but see Pires *et al.*, 2000).

Feminella (1996) studying the relationships between a gradient of permanence and macroinvertebrate assemblages, found a high correlation between EPT and an increase of permanence, what also is consistent with our results, although its importance are relative to the season analyzed (Figure 6). A higher EPT/OCH ratio in winter respect summer for all three flow categories can be related with the difference of habitat in both seasons with larger riffles in winter and more pools in summer (Williams, 1996). However, in the dry season, although several riffles are still present in permanent sites, they have a high OCH values, what could be related to a major presence of pools in summer because the habitat constriction or to life cycles of riffle families.

It has been proposed that a specific habitat can imply the presence of several macroinvertebrates with some characteristic traits adapted to the habitat that is “The habitat template theory” (Southwood, 1977, 1988). In that sense, in our study, the absence of significant traits in permanent sites could be related to high habitat variability, with riffles and pools segregated but always present, while in intermittent sites pools are dominant in at least in one season, and in ephemerals riffles are dominant. Moreover, as the disturbance is one of the agents generating spatial and temporal heterogeneity (Whiter & Harrod, 1997) the structure of the community and the evolution of the species strategies are affected. Intermittent and ephemeral streams are subjected to different types of disturbance that imply different responses of biological traits: the change of habitat into pools in summer in intermittent sites and the lack of flow in ephemeral sites in the dry season. In that sense, Wiens (2000) suggest that the evolution of behavior traits are often to be interpreted in the context of spatial heterogeneity, although the combined effects of temporal and spatial variability drive some adaptative traits. In our case, the relationship between spatial and temporal heterogeneity generates the presence of traits enclosing both heterogeneities. Aquatic stages, respiration, locomotion, food and feeding habits could be related to spatial heterogeneity, as their properties change between intermittent and ephemeral sites because the presence of pools and bedrock in intermittent and gravels/cobbles and riffles in ephemeral sites. On the other hand, maximal size, life cycle duration, potential number of reproductions per year, dispersal and resistance forms would be more related to the presence of temporal heterogeneity and affecting differently in intermittent and ephemeral sites.

As Townsend and Hildrew (1994) predicted, more disturbed sites had habitat generalist's individuals, with small size, high adult mobility and some life cycles outside the stream. In our ephemeral sites some of these traits appear as significant, as these localities are highly disturbed by a short duration of flow. Disturbance in river ecosystem have been defined in terms of intensity and frequency (Resh *et al.*, 1988), and the response of the system also depends on the degree of stability (Wishart, 1998). Ephemeral sites, because the presence of gravels and cobbles and low flow could be related with some sandbed rivers located in arid and semiarid lands with low taxonomical richness and highly resilient organisms (Wishart, 1998), exhibiting traits from r-species (Williams, 1996) as Baetidae, Caenidae, Culicidae, Chironomidae that present continuous life cycles (Gray, 1981; Gray & Fisher, 1981; Molles, 1985). Smaller individuals have been found in ephemeral sites at the beginning of the wet season (Williams, 1987, 1996) although in our case, maximal size not appears as significant, and that can be related with the sampling month far away from the colonization season. On the other hand, our results suggest that in ephemeral sites, the main way to colonization is made by drift from or flying adults laying eggs, without significant resistant forms, what is related to the high heterogeneity of the streams samples at basin scale (Figure 1 a-b). Thus, some ephemeral reaches can be connect to permanent o intermittent ones during wet period, providing organisms that disclose the role of core species in permanent and intermittent sites as refugia (Lake, 2000), and facilitating some of those core resilient species in front of resistant ones. Consequently, that would explain why resistance does not appear as significant. In fact, in mediterranean ecosystems, a predominance of resilient forms over resistance ones prevails (Fox & Fox, 1986). According to all of that, ephemeral sites would not have a unique and characteristic community (Delucchi & Peckarsky, 1989) as it derives from core species in permanent and intermittent sites with short life cycles and a fast growth.

In intermittent sites the presence of isolated pools is strongly related to the biological traits present. Temporary pools communities are composed by life history adapted taxa and random taxa that colonize and become extinct (Schneider & Frost, 1996). Predators (mainly Odonata and Heteroptera) are important taxa in pools exhibiting long life cycles (Schneider & Frost, 1996; Williams, 1996) and several reproductions per year, although their abundance can be affected by habitat duration (Bradshaw & Holzapfel, 1983; Dodson, 1987). Consequently, biotic interactions have to be stronger in these intermittent sites compared with ephemeral and permanent ones, because of the reduction of habitat in the first one (Gasith & Resh, 1999; Lake, 2000). Change of habitat structure in intermittent sites as isolated pools also enhance the presence of aerial breathers, because of the impoverished water quality in pools and lack of flow to renovate (Williams, 1996). As the isolated pools enhance the abundance of OCH organisms respect EPT, traits found are those belonged to them. In that sense, Usseglio-Polatera (1994) in a study in the Upper Rhône River found that Coleoptera traits are characteristic and different from the Ephemeroptera and Plecoptera with Trichoptera and Odonata displaying intermediate categories.

Relationships with the River Habitat Template

Although none organism is as specific from r or K (Pianka, 1970), the gradient of permanence found from ephemeral to permanent sites can suggest a spectrum of r to K strategies (*sensu* McArthur & Wilson, 1967). Ephemeral sites seem to exhibit r-biological traits, whereas intermittent sites present traits from K-species because the abundance of Coleoptera (Usseglio-Polatera, 1994). Similary, Poff & Allan (1995) associated stable hydrological ecosystems to specialist fish species and fluctuating ones with more generalist organisms. Furthermore, Biggs *et al.* (1998) looking at periphyton community related a habitat matrix defined by disturbance and resource supply to the taxa, identifying taxa with characteristic traits in each case. Thus, traits typical from communities subjected to a high disturbance were small in size, low in biomass, with strong attachment to the surface, high growth rates… what would agree with our results in macroinvertebrates in ephemeral sites. In undisturbed or more stable sites, community was segregated according to the resource supply. Physical structure in our study has been classified as flow and structural characteristics (see Figure 7) and both providing permanent, intermittent or ephemeral reaches. Permanent sites can be present in a diverse substrates conditions (e.g., a mix of bedrock, pools, cobbles, gravels, riffles) but aways should present a high winter and summer flow. Besides, intermittent and ephemeral reaches only can exist if a low flow is present in both seasons. The three situations manifest a different level of spatial heterogeneity. Thus, ephemeral sites because the low flow in winter and the dry bed in summer present a very low spatial heterogeneity compare with intermittent sites with pools in summer. Finally, permanent sites exhibit the maximum spatial heterogeneity, as they in both seasons pools and riffles over a variety of substrates are present (Figure 7). Moreover, permanent sites may act as a refugee of riffles taxa coming from ephemeral and intermittent sites. Similarly to this spatial heterogeneity increasing from ephemeral to permanent reaches, a temporal heterogeneity is observed too in the contrary direction. Permanent habitats are temporally more stable than intermittent and ephemeral ones. Consequently, because permanent, intermittent and ephemeral reaches present different spatial and temporal heterogeneity, the "River Habitat Template" (Townsend and Hildrew, 1994) can be applied to our results. In Figure 8, the application of the "River Habitat Template" to our results is presented. Low temporal and high spatial heterogeneities correspond to permanent sites with a mix of riffles/pool/core with few changes between wet and dry period. Besides that, intermittent sites present a higher temporal heterogeneity what affects to the community loosing riffles species in summer and sheltering species with K-traits. Finally, in ephemeral sites, the high temporal and low spatial heterogeneity imply a lower number of taxa with riffle and core species dominant, and characteristic r-species traits. Comparisons between Figure 8 and the predictions of traits in the "River Habitat Template" (see Figure 4) in Townsend & Hildrew, 1994) indicate that a high congruity with our results is present.

Several authors have not found conformity with "River Habitat Template" and traits (Resh *et al.*, 1994; Statzner *et al.*, 1997) because the trade-offs among traits and the use of different taxa. On the other hand, Persat *et al.* (1994) also found no significant relationship between some fish traits in Upper Rhône River and the "River Habitat Template" that seems a result of the scale of observation, the evolution of fishes in the area and the history of the river. In our case, the quite good congruity with our findings and the "River Habitat Template" theory confirm the utility of groups of taxa with similar traits to confirm ecological theories (Statzner *et al.*, 1997).

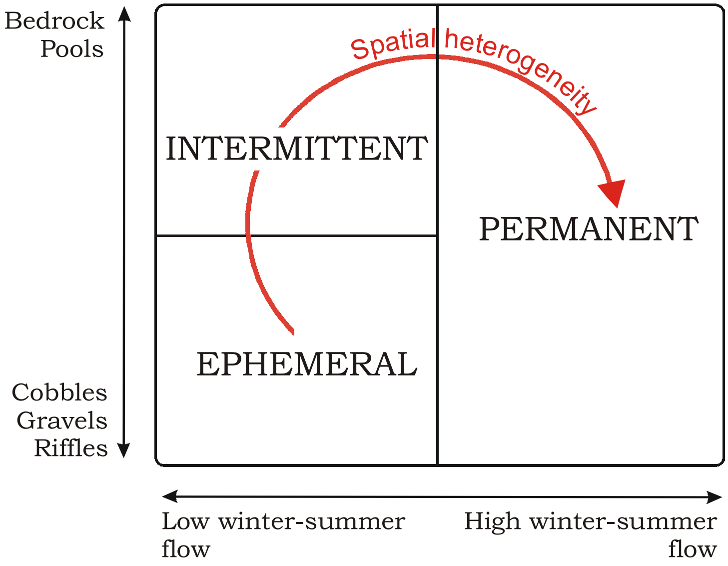


Figure 7. Categorization of habitat by flow and substrate, for permanent, intermittent and ephemeral sites. A increase of spatial heterogeneity from ephemeral to permanent sites is noticed.

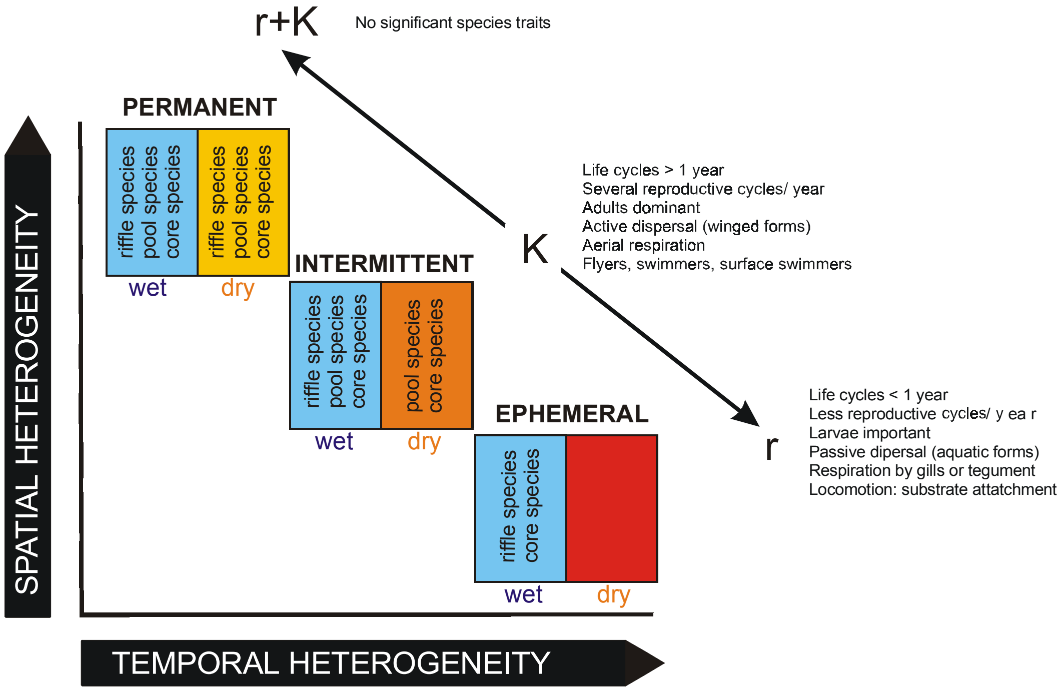


Figure 8. Application of permanent, intermittent and ephemeral conditions to the "River Habitat Template" from Townsend & Hildrew (1994).

Concluding remarks

Mediterranean streams are known for their flow fluctuations along and between years that may cause, mostly in summer, very deep changes in environmental conditions (Gasith & Resh, 1999). Although a different macroinvertebrate assemblage is observed between seasons in all sites (Figure 4), more fine information can be obtained with the categorization of sites in permanent, intermittent and ephemeral. Temporary changes in mediterranean rivers have been related to the climate (e.g. Gasith and Resh, 1999), but other factors may influence and increase or decrease its importance. In our study, either climate or geomorphology of the area sampled interferes on the temporality of rivers and macroinvertebrate responses, providing heterogeneity on responses at different scales. In mediterranean rivers, all these factors can have important consequences in designing of biomonitoring programs in these areas, and methods adapted to these areas have to be developed and tested (Bonada *et al.*, Chapter 1).

Although natural disturbance is present in mediterranean rivers and streams (McElravy *et al.*, 1989; Resh *et al.*, 1990; Gasith & Resh, 1999) and despite the high spatial and temporal heterogeneity observed, mediterranean rivers seems very stable compare with other arid and semiarid areas (Wishart, 1998), as the habitat and temporality appear as the main organizer factors of the macroinvertebrate community. This study agrees with the idea that natural disturbances are determinants to structure of aquatic ecosystems (Fisher & Grimm, 1991; Stanley & Fisher, 1992).

The presence of such variability in streams and responses enhance a high biodiversity in mediterranean rivers, and the moderate stress conditions could be responsible to it (Bond, 1983; Bonada *et al.*, Chapter 3). This enlightened the importance of preservation of small streams from headwaters (as those of Sant Llorenç Natural Park) together with the summer pools in the entire basin, as these are the biodiversity refuges for macroinvertebrates in Mediterranean basins (Vidal-Abarca *et al.*, 1996).

GLOSSARY

Permanent: Is referred to rivers and streams with flowing water either during wet and dry periods.

Intermittent: Is referred to rivers and streams that present isolated pools during dry period. These pools can dry up or not, depending on the length of the dry season.

Ephemeral: Is referred to rivers and streams that dry up completely in dry period. In general they only contain water after heavy rain periods.

Temporay: Is applied to rivers and streams that dry up or recede in isolated pools. Both, intermittent and ephemeral rivers and streams would be included in this category.

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Annex 1. Physical structure estimated in each sampling site.

Site	%Bedrock	%Pools	Winter flow (l/s)	% winter flow	Summer flow (l/s)	% summer flow
RP1	0	0	2.92	0.83	DRY	0
RP2	90	70	51.75	14.79	10.84	52.19
RP3	0	0	13.76	3.93	DRY	0
RP4	80	70	19.05	5.44	0.07	0.34
RP5	0	60	3.53	1.01	1	4.81
RP6	60	70	25.9	7.4	0	0
RP7	40	80	137.31	39.23	2.2	10.59
GA1	15	10	278.66	79.62	9.66	46.51
GA2a	15	50	0.1	0.03	DRY	0
GA2c	0	0	343	98	DRY	0
RN1	30	20	164.53	47.01	20.77	100
RN2	40	20	57.57	16.45	DRY	0
RN3	0	10	114.14	32.61	DRY	0
MR1	70	20	191	54.57	0.29	1.4
MR2	100	30	350	100	15.58	75.01
MR3	50	40	159.4	45.54	18.67	89.89
MR4	40	80	54.78	15.65	0	0
MR6	90	90	200	57.14	0	0
MR7	80	60	208.56	59.59	1	4.81
MR8	90	70	6.24	1.78	1	4.81
MR9	0	0	3.49	1	DRY	0
MR10	50	60	16.84	4.81	0	0
MR12	20	70	152.47	43.56	7.73	37.22
SI1	60	80	1	0.29	0	0
SI2	70	10	33.86	9.67	DRY	0

Annex 2. Ranking of sites according to each physical parameter.

	% Bedrock		**% Pools**		**% Winter flow**		**% Summer flow**	
%	*Site*	*Rank A*	*Site*	*Rank B*	*Site*	*Rank C*	*Site*	*Rank D*
100	MR2	25			MR2	25	RN1	25
90 to 99	RP2	23	MR6	25	GA2c	24		
	MR6	23						
	MR8	23						
80 to 89	RP4	20.5	RP7	23			MR3	24
	MR7	20.5	MR4	23				
			SI1	23				
70 to 79	MR1	18.5	RP2	19	GA1	23	MR2	23
	SI2	18.5	RP4	19				
			RP6	19				
			MR8	19				
			MR12	19				
60 to 69	RP6	16.5	RP5	15				
	SI1	16.5	MR7	15				
			MR10	15				
50 to 59	MR3	14.5	GA2a	13	MR7	21	RP2	22
	MR10	14.5			MR1	21		
					MR6	21		
40 to 49	RP7	12	MR3	12	RN1	18	GA1	21
	RN2	12			MR3	18		
	MR4	12			MR12	18		
30 to 39	RN1	10	MR2	11	RP7	15.5	MR12	20
					RN3	15.5		
20 to 29	MR12	9	RN1	9				
			RN2	9				
			MR1	9				
10 to 19	GA1	7.5	GA1	6	RN2	13	RP7	19
	GA2a	7.5	RN3	6	MR4	13		
			SI2	6	RP2	13		
0.1 to 9	RP1	3.5	RP1	2.5	SI2	6	RP5	16
	RP3	3.5	RP3	2.5	RP6	6	MR8	16
	RP5	3.5	GA2c	2.5	RP4	6	MR7	16
	GA2c	3.5	MR9	2.5	MR10	6	MR1	16
	RN3	3.5			RP3	6	RP4	16
	MR9	3.5			MR8	6		
					RP5	6		
					MR9	6		
					RP1	6		
					SI1	6		
					GA2a	6		
0							SI1	11
							RP6	11
							MR6	11
							MR4	11
							MR10	11
DRY							RP3	4.5
							RP1	4.5
							RN3	4.5
							RN2	4.5
							SI2	4.5
							MR9	4.5
							GA2c	4.5
							GA2a	4.5

Annex 3. Biological traits and categories according to Usseglio-Polatera at al. (2000).

TRAITS	n°	MODALITIES
Maximal size	1	≤0.25 cm
	2	>0.25-0.5 cm
	3	>0.5-1 cm
	4	>1-2 cm
	5	>2-4 cm
	6	>4-8 cm
	7	>8 cm
Life duration	1	≤ 1 year
	2	>1 year
Potential number of reproduction cycles per year	1	<1
	2	1
	3	>1
Aquatic stages	1	egg
	2	larva
	3	pupa
	4	adult
Reproduction	1	ovoviviparity
	2	isolated eggs, free
	3	isolated eggs, cemented
	4	clutches, cemented or fixed
	5	clutches, free
	6	eggs or clutches, in vegetation (endophytic)
	7	clutches, terrestrial
	8	asexual reproduction
Dispersal	1	aquatic passive
	2	aquatic active
	3	aerial passive
	4	aerial active
Resistance forms	1	eggs, statoblasts, gemmunles
	2	cocoons
	3	cells against desiccation
	4	diapause or dormancy
	5	none
Respiration	1	tegument
	2	gill
	3	plastron
	4	spiracle (aerial)
Locomotion and substrate relation	1	flier
	2	surface swimmer
	3	swimmer
	4	crawler
	5	burrower (epibenthic)
	6	interstitial (endobenthic)
	7	temporarily attached
	8	permanently attatched
Food	1	fine sediment + microorganisms
	2	detritus <1 mm
	3	plant detritus ≥1 mm
	4	living microphytes
	5	living macrophytes
	6	dead animal ≥1 mm
	7	living microinvertebrates
	8	living macroinvertebrates
	9	vertebrates
Feeding habits	1	absorber
	2	deposit feeder
	3	shredder
	4	filter-feeder
	5	piercer (plant or animals)
	6	predator (carver/engulfer/swallower)
	7	parasite, parasitoid

Annex 4. Taxa list and biological traits group associated indicating the maximum affinity category according to Usseglio-Polatera at al. (2000).

	gr. / sgr.
Dugesia sp.	c1
Oligochaeta	h
Erpobdella sp.	c1
Glossiphoniidae	b1
Ancylus fluviatilis	e2
Radix sp.	e1
Lymnaea sp.	c2
Physa acuta	e2
Gyraulus sp.	e2
Pisidium sp.	b2
Gammaridae	b1
Hydracarina	-
Baetis sp.	e2
Cloeon sp.	e1
Caenis sp.	f
Ephemerella sp.	f
Heptageniidae	f
Leptophlebiidae	f
Chloroperlidae	c2
Leuctridae	f/c
Nemoura sp.	f
Perlodidae	c
Aeshnidae	d
Coenagrionidae	d2
Cordulegasteridae	d1
Corduliidae	d1
Gomphidae	d1
Lestidae	d2
Libellulidae	d/c
Sigara lateralis	g1
Hesperocorixa linnaei	g1
Micronecta cf. *scholtzi*	e3
Parasigara perdubia	g1
Parasigara sp.	g1
Aquarius najas	-
Gerris argentatus	g3
Gerris brasili	g3
Gerris gibbifer	g3
Gerris lacustris	g3
Hydrometra stagnorum	g2
Mesovelia vittigera	g2
Notonecta maculata	g2
Notonecta sp.	g2
Velia caprai	g1
Nepa cinerea	g3
Naucoris maculatus	g2
Plea minutissima	g2
Dryops sp.	g1
Agabus sp.	g3
Bidessus sp.	g2
Graptodytes sp.	g2
Dytiscus marginatus	g3
Laccobius sp.	g1
Laccophilus sp.	g2
Meladema sp.	g3
Metaporus sp.	g2
Stictonectes sp.	g2
Yola sp.	g2
Oulimnius sp.	e3
Potamophylus sp.	e3
Riolus sp.	e3
Gyrinus sp.	g3
Haliplus sp.	g2
Helodes sp.	e3
Helophorus sp.	g1
Limnebius sp.	g1
Hydrochus sp.	g1
Berosus sp.	g3
Helochares sp.	g1
Hydrous (=Hydrophilus) sp.	g3
Laccobius sp.	g1
Hydraena sp.	g1
Limnebius sp.	g1
Beraea sp.	e2
Glossosomatidae	e2
Hydropsyche sp.	e1
Hydropsyche exocellata	e1
Hydropsyche sp1	e1
Hydropsyche cf. *bulbifera*	e1
Hydropsyche gr. *pellucidula*	e1
Hydroptila sp.	e2
Mystacides sp.	e2
Limnephilus sp.	f
Mesophylax aspersus	f
Odontocerum albicorne	c2
Wormaldia sp.	e1
Polycentropus sp.	e1
Tinodes waeneri	e2
Tinodes maculicornis	e2
Tinodes sp.	e2
Antomyiidae	c2
Athericidae	d2
Ceratopogonidae	c2
Chironomidae	e/c
Culicidae	e3
Dolichopodidae	g3
Dixidae	e1
Empididae	c2
Limoniidae	c
Psychodidae	e2
Simuliidae	e
Stratiomyidae	e3
Tabanidae	g3
Tipulidae	c1

Annex 5. Maximum affinity value for each trait and group/subgroup from data provided by Usseglio-Polatera.

var1= Maximal size; **var2**=Life duration; **var3**=number reproductioncycles per year; **var4**=aquatic stages; **var5**=reproduction; **var6**=dispersal; **var7**=resistance forms; **var8**=respiration; **var9**=locomotion and substrate relation; **var10**=food; **var11**=feeding habits.

	Biological Trait										
gr. / sgr.	**var1**	**var2**	**var3**	**var4**	**var5**	**var6**	**var7**	**var8**	**var9**	**var10**	**var11**
b1	5	2	2	1	1	1	5	1	4	8	3
b2	7	2	2	2	1	1	5	2	5	2	5
c	4	2	2	2	4	2	5	1	4	8	7
c1	4	2	2	1 / 2	4	2	5	1	4	8	7
c2	4	1	2	2	4	1	5	1	4	8	7
d	5	2	1	2	6	4	5	2	4	8	7
d1	5	2	1	2	2	4	5	2	4	8	7
d2	4	1	2	2	6	4	5	2	4	8	7
e	3	1	2	1	4	1	5	1	4	4	4
e1	3	1	2	1	4	1	5	1	4	4	5
e2	3	1	2	1	4	1	5	1	4	4	4
e3	2	1	2	2	4	4	5	2	4	4	4
f	4	1	2	2	4	4	5	2	4	3	3
g1	2	2	2	1	4	4	5	4	3	4	3
g2	2	2	3	2	4	4	5	4	3	8	6
g3	4	2	2	2	4	4	5	4	4	8	6

Chapter 6

TRICHOPTERA (INSECTA) FROM IBERIAN MEDITERRANEAN RIVER BASINS: taxonomic notes and ecological requirements.

INTRODUCTION

Studies on caddisfly in the Iberian Peninsula date from the middle of the nineteen-century; although the major part of the works have been performed more recently (see González *et al.*, 1992). Most of the taxonomic studies performed are located in northern and central areas (García de Jalón, 1982; González *et al.*, 1987), but recent contributions from southern areas are increasing, with some faunistic studies (e.g., Ruiz *et al.*, 2001) and new species findings (e.g., Zamora-Muñoz *et al.*, 2002). Along the Mediterranean coast, caddisfly species are known by specimens gathered by several authors (e.g., see examples in González *et al.*, 1992; Malicky, 2002) or by species list obtained by ecological studies (e.g., Puig *et al.*, 1981; Herranz & García de Jalón, 1984; Gallardo-Mayenco, 1993; Gallardo-Mayenco *et al.*, 1998).

Mediterranean fauna have been described as highly diverse, with a considerable level of endemicity and complexity as the result of the interaction of complex historical and ecological factors (Balletto & Casale, 1989). In the Iberian Peninsula the Trichoptera order comprises numerous species with up to 331 records known (Vieira-Lanero, 2000 revision updated with posterior descriptions by González & Ruiz, 2001; and Zamora-Muñoz *et al.*, 2002) including a high number of endemic species (González *et al.*, 1987). It represents a higher number of caddisfly species than other European regions as England, with 207 species (Edington & Hildrew, 1995; Wallace *et al.*, 1990), but similar to other Mediterranean countries in Italy (with 381 species —Cianficconi, 2002).

Here, we present a list of 91 caddisfly species obtained of identify 12499 larvae, 177 pupae and 261 adults, collected in Mediterranean climate rivers. For each species we include several taxonomic and ecological notes. Most of the data were obtained from the GUADALMED Project, although many other records from other Mediterranean rivers have been also included.

METHODOLOGY

Sampling area

Trichoptera were collected mainly from 10 Iberian basins situated along the Mediterranean coast and selected under the Guadalmed project: Besòs, Llobregat, Mijares, Turia, Júcar, Segura, Almanzora, Aguas, Adra and Guadalfeo (an extensive description of sampled basins can be found in Robles *et al.*, in press). Moreover, data obtained from Foix, Tordera, Ter, Noguera Ribagorçana and Guadalquivir basins have also been included (information about these basins can be found in Prat *et al.*, 1999, 2000 and 2001; Rieradevall & Prat, 2000; Solà, 2001). Overall, the studied area is subjected to a mediterranean climate (Köppen, 1923), with annual precipitation going from less than 300 mm in the more arid basins in the southeast to over 800 mm in northern basins or in some other areas. Limestone and sedimentary materials mainly compose geology, although some siliceous areas are also present as in Sierra Nevada, Pyrenees and Montseny ranges. Sclerophyllous and evergreen trees and shrubs mainly compose basin vegetation, although in some areas deciduous and coniferous forests are present. As in other mediterranean regions, sampled basins have been largely affected by human activities (Trabaud, 1981) as agriculture, cattle, urbanization, salinization, water abstraction and regulation... (Conacher & Sala, 1998). All these factors have contributed to the river alteration in a direct or indirect way (Prat, 1993).

Sampling procedure

Caddisfly arvae and pupae were obtained sampling all available habitats with a kick net of 250 μm mesh size. They were preserved in formalin (4%) or alcohol (70%) before beeing identified in the lab until the maximum taxonomic level possible. When it was possible, some larvae or pupae were collected in the field, transported in the lab and reared to obtain pupae and adults, using a similar method as in Vieira-Lanero (1996) (see Figure 1a). This system consists in tank with controlled water temperature (–10 to 40°C). A water pump recirculates and cleans it, providing oxygen at the same time. Purified water at 19°C was used in the circuit, and the system was exposed to natural light. Larvae from last instars were located in cages separately by sampling sites or rivers (Figure 1b). Each cage had a substrate composed by clean gravels. For shredders, food was supplied using leaf-litter taken from riverbeds. For grazers, stones with periphiton were collected in the same site were larvae was obtained. We were not able to rear predators and filters-feeders.

Figure 1. 1a. Rearing system.
1b. Cages to rear caddisfly larvae. Larvae were grouped in cages by sites.
1c. Pupae collected in the field and ready to emerge,
1d. Light trap working in the field.

On the other hand, adults were also obtained in the field catching them among riparian vegetation with a net or using a light trap with an UV-light connected to a car battery (Figure 1c). To identify adults and pupae specimens, genitalia were digested in a 10% KOH solution, at 90°C constant temperature. Once digested, genitalia was observed and identified under the stereoscope or microscope in a glycerin solution (M. A. González, pers. comm.).

Checklist structure and taxonomical and ecological notes

Trichoptera species are presented following the taxonomical classification according to Wiggins (1998). However, we have omitted subgenera because they are not widely used by tricopterologists (Vieira-Lanero, 2000). For each species, the number of larvae (L), pupae (P) and adults are presented. In general only identifications from males specimens are presented. Females were only identified where they appear jointly with several males (e.g., in *Agapetus*), or they belong to families where females are quite well known (e.g., Limnephilidae). For pupae and adults, the months where they were collected are shown in brackets.

Sites where the species were found are classified by basins and coded by a letter and a number. In Annex 1, the exact location of each site is presented. In some cases, a question mark (?) is added before sampling localities because the identity of the larvae found was not sure.

For some species, taxonomic remarks are presented including information about subspecies or morphological characteristics. Most of the distributions and ecological notes for each species were obtained from the recent review of caddisfly made by Vieira-Lanero (2000) and the faunistic list from González *et al.* (1992). Moreover, for each species we have compared the general ecology and distribution with the data obtained in this study (Bonada *et al.*, Chapter 7 and 8) and the general Data Base from GUADALMED Project.

TRICHOPTERA SPECIES IN THE IBERIAN MEDITERRANEAN BASINS

Suborder SPICIPALPIA

Family **RHYACOPHILIDAE** Stephens, 1836

Subfamily *Rhyacophilinae* Stephens, 1836

Rhyacophila Pictet, 1834

1- *Rhyacophila dorsalis* (Curtis, 1834)

MATERIAL STUDIED: 324L, 10P♂3P♀ (IV, V, VII, VIII), 3♂ (IV, V)
Ter Basin: T3, T4, T8, T10
Tordera Basin: ToM8, ToM12
Besòs Basin: B25, B32
Llobregat Basin: L38, L42, L54, L56, L57, L60a, L60c, L61, L68, L77
Mijares Basin: MI4
Turia Basin: TU1, TU2, TU4, TU6, TU9
Júcar Basin: JU8

TAXONOMIC REMARKS

The males collected in Llobregat River correspond to the "Pyrenees form" (H. Malicky, pers. comm.) but more information is still necessary to consider them as the subspecies *Rh. dorsalis obtusidens* (Malicky, 2002).

DISTRIBUTION AND ECOLOGY

Species widely distributed from central to southern Europe. In the Iberian Peninsula it has been found in central and northern Spanish areas (González *et al.*, 1992).

According to Décamps (1967), *Rh. dorsalis* is found mostly in rivers at medium or low altitudes under 500 m. In the Iberian Peninsula it has been recorded in calcareous areas (García de Jalón, 1982). In the sampled Mediterranean area it is frequent both in calcareous and siliceous headwaters and middle parts from 220 m to 1200 m. Larvae can tolerate a wide range of environmental conditions (Moretti & Mearelli, 1981; Bonada *et al.*, Chapter 8), although it has been considered as an intolerant species in rivers of central Spain (González del Tánago & García de Jalón, 1984).

2- Rhyacophila evoluta McLachlan, 1879

MATERIAL STUDIED: 43L, 1P♂ (V), 3♂ (VII)
Ter basin: T1, T2, T8, T9, T10, T11

DISTRIBUTION AND ECOLOGY

Central and southwestern European species. In the Iberian Peninsula it has been only recorded in northwestern basins.

This species has been recorded in Pyrenees at higher altitudes (between 600-2500 m — Décamps, 1967) than *Rh. meridionalis* and *Rh. mocsaryi tredonensis* (Bautista, 1980). Larvae presented here have been found only in the siliceous and pristine headwaters from Pyrenees, over 1200 m. *Rh. evoluta* was extensively recorded in the middle reaches of the Llobregat River (Puig *et al.*, 1981). In the same sampling sites where Puig *et al.* (1981) recorded *Rh. evoluta*, we have now identified all specimens as mainly *Rh. dorsalis* (with some *Rh. relicta* and *Rh. fasciata*). Reviewing the original material identified by Puig *et al.* (1981), we found only *Rh. dorsalis*. Therefore, all old records of *Rh. evoluta* from Llobregat river belong to *Rh. dorsalis* and the data from Puig *et al.* (1981) has to be referred to this species.

3- Rhyacophila fasciata Hagen, 1859

MATERIAL STUDIED: ?3L, 2P♂ (IV, VII)
Ter Basin: T10
Llobregat Basin: L43, L60a

TAXONOMIC REMARKS

The pupae found in Llobregat River (L60a) are identified as *Rh. fasciata denticulata*. Although the presence of *Rh. fasciata* in the Iberia Peninsula should be confirmed (González *et al.*, 1992), Malicky & Sipahiler (1993) concluded that the Iberian *Rh. denticulata* is a subspecies from *Rh. fasciata*, even though larvae are very distinct (Vieira-Lanero, 2000) with different length of the sword process. The sclerites found in the cocoon in our specimens present a long sword process, what does not correspond to the larval description of *Rh. denticulata* (Despax, 1928). Moreover, some larvae collected in Ter and Llobregat rivers present morphology similar to *Rh. fasciata*, with a long sword process and an apotome with a black posterior patch with black muscle insertions (according to Buholzer, 1978 and Waringer & Graf, 1997). Consequently, more larvae and pupae should be analyzed to ensure with certainty the presence of *Rh. fasciata* in the Iberian Peninsula.

DISTRIBUTION AND ECOLOGY

European and southwestern Asian species.

In our sampled basins, the individuals collected have been found in middle reaches of calcareous streams, coexisting with *Rh. dorsalis* and *Rh. relicta.*

4- Rhyacophila intermedia McLachlan, 1868

MATERIAL STUDIED: 2L, 1♂ (VII)
Noguera Ribagorçana Basin: OUT0m, INLET

DISTRIBUTION AND ECOLOGY

Central and southwestern European species. In the Iberian Peninsula is found in northern basins.

It has found in pristine headwaters at high altitudes by several authors (see Vieira-Lanero, 2000). In our study it has been found over 2000m in pristine headwaters.

5- Rhyacophila laevis Pictet, 1834

MATERIAL STUDIED: 2L

Noguera Ribagorçana Basin: OUT200m, INLET

DISTRIBUTION AND ECOLOGY

Central and southwestern European species. In the Iberian Peninsula it is found only in the north-east area.

Larvae are typical from headwaters of high mountain pristine rivers at high altitudes (Décamps, 1967).

6- Rhyacophila meridionalis Pictet, 1865

MATERIAL STUDIED: 150L, 2P♂ (VIII), 1♂ (X)

Ter Basin: T9, T10, T12, TM2, TM5
Tordera Basin: ToM5, ToM6, ToM8, ToM10, ToM12, ToM13, ToM15
Besòs Basin: B32
Llobregat Basin: L54, L56
Segura Basin: SE01
Almanzora Basin: AL6
Adra Basin: AD5
Guadalfeo Basin: GU1, GU5, GU11, GU15

TAXONOMIC REMARKS

Most of the specimens collected in Mediterranean northern basins (i.e., Ter, Tordera, Besòs and Llobregat) present a head colour pattern as in the Décamps original description and the northwest larvae (Vieira-Lanero, 2000), whereas larvae found in southern basins (Segura, Almanzora, Adra and Guadalfeo) are similar to the ones described in Zamora-Muñoz *et al.* (1997).

DISTRIBUTION AND ECOLOGY

Southwestern European species. In the Iberian Peninsula it is distributed preferently in northern areas, although records from southern areas are found (Zamora-Muñoz *et al.*, 1997).

Rh. meridionalis is present in a wide range of altitudes (Vieira-Lanero, 2000). It appears intolerant to high discharge what can constrain its downstream distribution (Zamora-Muñoz *et al.*, 1997). In the sampled rivers it has been found in riffles of siliceous and calcareous pristine headwaters. González del Tánago & García de Jalón, (1984) considered that this species is intolerant to pollution. According to the results found in Bonada *et al.* (Chapter 8), it is very sensitive species to conductivity, suspended solids and ammonium, but may tolerate some phosphorous.

7- Rhyacophila mocsaryi Klapálek, 1898

MATERIAL STUDIED: 37L

Ter basin: T3, T4, T7, T8, T10, TM4, TM5

TAXONOMIC REMARKS

In the Iberian Peninsula all specimens belong to the subspecies *tredosensis* (González *et al.*, 1992).

DISTRIBUTION AND ECOLOGY

This species has been recorded in the Iberian Peninsula, Pyrenees, Caucasian and Balkans.

R. mocsaryi tredosensis has been collected in mountain headwaters rivers (Décamps, 1967; Bautista, 1980; García de Jalón, 1982) with a pristine water quality (González del Tánago & García de Jalón, 1984), as in our case.

8- Rhyacophila munda McLachlan, 1862

MATERIAL STUDIED: 141L, 4P♂3P♀ (I, IV, VII), 1♀ (V)

Mijares Basin: MI7
Turia Basin: TU12
Júcar Basin: JU5, JU9, JU12, JU13, JU19
Segura Basin: SE1, SE3, SE4, SE5, SE7, SE16
Almanzora Basin: AL2, AL6, AL10, AL11
Aguas Basin: AG1
Adra Basin: AD2, AD3, AD4
Guadalfeo Basin: GU4, GU5, GU6, GU7, GU8, GU9, GU10, GU11, GU12, GU13, GU14, GU15, GU16

TAXONOMIC REMARKS

Larvae from *Rh. munda* have been traditionally distinguished from *Rh. lusitanica* by a different length of the sword process (Viedma & García de Jalón, 1980). However, Zamora-Muñoz (pers. comm.) found specimens of *Rh. munda* with a longer process than the expected. Most of the specimens collected in Mijares, Turia, Júcar, Segura, Almanzora and Aguas present a long sword process, and head and pronotum patterns are similar to *Rh. lusitanica*. Although some difficulties have been found when identifying our specimens, we have provisionally named them as *Rh. munda*, because *Rh. lusitanica* is more constrained to central and northwest Spanish areas (Vieira-Lanero, 2000), whereas *Rh. munda* is widely distributed and very abundant in south Spain. More pupae and adults of all these basins are needed to ensure larvae identifications.

This species shows a strong similarity with the undescribed *Rh. fonticola* present in southern Spain, both species coexisting in some sites (Ruiz *et al.*, 2001). When *Rh. munda* and a specimen of *Rh. fonticola* (loan from R. Vieira-Lanero) are compared some differences are observed in head patterns. Our specimens of *Rh. munda* do not present conspicuous brown dots in the head ventrally, contrarily to the specimen of *Rh. fonticola*. Moreover, an aboral V-shape brown spot is present in the apotome of *Rh. fonticola* but is not as clear in *Rh. munda*.

DISTRIBUTION AND ECOLOGY

Southwestern European and north African species. In the Iberian Peninsula is widely distributed (Vieira-Lanero, 2000). However, we did not find *Rh. munda* in northern Mediterranean basins.

Contrary to *Rh. fonticola* associated to siliceous springs (Ruiz *et al.*, 2001), *Rh. munda* species is associated with midstream reaches (Vieira-Lanero, 2000; Bonada *et al.*, Chapter 7) in permanent and temporary streams (García de Jalón & González del Tánago, 1986). It appears able to tolerate a wide range of conditions and it is very abundant in sedimentary substrates within marl basins in the southeast Spain (Bonada *et al.*, Chapter 8). It has been identified as tolerant species (González del Tánago & García de Jalón, 1984), and in our case it is even present at high suspended solids concentration and low riparian and biological indexes (Bonada *et al.*, Chapter 8).

9- Rhyacophila nevada Schmid, 1952

MATERIAL STUDIED: 160L, 6P♂ (II, IV, VII, X), 1♂ (VII)

Almanzora Basin: AL6, AL7
Segura Basin: SE1, SE3, SE4, SE8
Adra Basin: AD4
Guadalfeo Basin: GU1, GU2, GU3, GU4, GU5, GU6, GU7, GU9, GU10, GU11, GU12, GU13, GU14, GU15

TAXONOMIC REMARKS

Recently, after analyzing few individuals, Malicky (2002) has considered *Rh. nevada* as sub-species of *Rh. dorsalis*. According to Zamora-Muñoz & Alba-Tercedor (1992) both species have distinct larvae, differentiated by larval size and colour patterns of head and pronotum. Except in few larvae, head patterns of all specimens collected in northern basins, where only *Rh. dorsalis* is present, correspond well to *Rh. dorsalis* in the Zamora-Muñoz's key. On the other hand, in southern basins most of the individuals fit under *Rh. nevada*, and few have features more typical of *Rh. dorsalis*. Therefore, in general we can accept that larvae of *Rh. dorsalis* and *Rh. nevada* are distinct along the Spanish Mediterranean coast.

DISTRIBUTION AND ECOLOGY

Endemic species from the Iberian Peninsula where has been recorded exclusively in southern areas, replacing *Rh. dorsalis* which is present in central and northern basins (Bonada *et al.*, Chapter 8).

It prefers mountain headwaters at high altitudes. In the sampled basins *Rh. nevada* display an ecological profile very different from *Rh. dorsalis*. *Rh. nevada* is restricted to pristine headwaters with predominant siliceous basins, beeing more sensitive to water quality than *Rh. dorsalis* (Bonada *et al.*, Chapter 8). Consequently, because the observed differences in larval morphology and ecology of both species, and because the few specimens analyzed by Malicky, we have considered them as different species. More studies based in morphological, ecological and genetic features should be performed to confirm the identity of *Rh. nevada*.

10- Rhyacophila cf. *occidentalis* McLachlan, 1879

MATERIAL STUDIED: 24L

Adra Basin: AD5
Guadalfeo Basin: GU1, GU11, GU15

TAXONOMIC REMARKS

Larvae from Adra and Guadalfeo are similar to *Rh. occidentalis* but no mature pupae or adults were available.

DISTRIBUTION AND ECOLOGY

Southwestern European species. In the Iberian Peninsula it is found in northern basins although it has been also recorded in some southern areas (see González *et al.*, 1992).

Rh. occidentalis prefers mountain headwaters at higher altitudes (see Vieira-Lanero, 2000). In our basins it has been found in siliceous areas until 1860m. Although González del Tánago & García de Jalón (1984) considered *Rh. occidentalis* a pollution-tolerant species we have found it in pristine rivers with high biological and riparian quality (Bonada *et al.*, Chapter 8).

11- Rhyacophila pascoei McLachlan, 1879

MATERIAL STUDIED: 1L

Guadalfeo Basin: GU16

DISTRIBUTION AND ECOLOGY

Central and southern European species. In the Iberian Peninsula it has been recorded in central and southern basins (González *et al.*, 1992).

This species has been found in rivers with high contents of sulphates and carbonates concentrations in southern basins (García de Jalón & González del Tánago, 1986). In our sampled basins, larvae of *Rh. pascoei* was found in a middle reach of a siliceous basin with a fair biological quality.

12- Rhyacophila relicta McLachlan, 1879

MATERIAL STUDIED: 39L

Ter Basin: T10, T12
Tordera Basin: ToM9
Llobregat Basin: L42, L54, L64, L68, L60a, L67

DISTRIBUTION AND ECOLOGY

Endemic species from the Iberian Peninsula and Pyrenees.

This species has been found very abundant in middle rivers (see Vieira-Lanero, 2000). We also have recorded it in headwaters but infrequent. According to González del Tánago & García de Jalón (1984) Rh. relicta is an intolerant species to pollution.

13- Rhyacophila gr. tristis Pictet, 1834

MATERIAL STUDIED: 102L, 6♂ (V, VII, VIII)

Ter Basin: T2, T3, T5, T8, T10, T11, TM4, TM5
Tordera Basin: ToM13
Besòs Basin: B32
Llobregat Basin: L44, L45, L54, L56, L60a
Noguera Ribagorçana Basin: OUT0m, OUT200m, INLET
Júcar Basin: JU7

TAXONOMIC REMARKS

The imago found in Mongrony River (Oriental Pyrenees) has several taxonomic features similar to *Rh. aquitanica* cited by Navás in closer areas (see González *et al.*, 1992). However, this specimen has been considered as *Rh.* gr. *tristis* because the absence of key characters to differentiate both species with certainty and the high variability known in *Rh. tristis* males (M. A. González, pers. comm.). In the same way, there are difficulties to distinguish larvae of *Rh. tristis* and *Rh. aquitanica*. Buholzer (1978) observed that Rh. tristis does not present ventral transversal stripes in the cephalic capsule, whereas *Rh. aquitanica* does. In the northwest of Spain, where only *Rh. tristis* has been found, larvae present transversal stripes (R. Vieira-Lanero, pers comm.), as in our specimens. Consequently, we have included all specimens into the *Rh.* gr. *tristis*.

DISTRIBUTION AND ECOLOGY

Central and southern European species and Anatolia. In the Iberian Peninsula is restricted to northern and central basins.

Is a common species from headwaters with a wide altitudinal range (Vieira-Lanero, 2000). We have found larvae in calcareous and siliceous rivers, reaching the 2000 m in the Pyrenees. *Rh. tristis* is a species considered very sensitive to pollution. Jointly with *Rh. nevada,* is the member of the family more sensitive to environmental quality variables (Bonada *et al.*, Chapter 8).

14- Other RHYACOPHILIDAE

In Segura Bain (site SE3) it has been found (A. Mellado pers. comm.) one larvae of a Rhyacophilidae with lateral abdominal gills composed by 3 filaments, which do not correspond to any Rhyacophilidae group (Figure 2). The rarity of this specimen suggests that further specific studies of adults and larvae of should be done in the area.

Figure 2. General view and detail of abdominal gills from the Rhyacophilid collected in Segura basins, with 3 gills in each side of abdominal segments (picture from A. Mellado).

Family **GLOSSOSOMATIDAE** Wallengren, 1891

Subfamily *Agapetinae* Martynov, 1913

Agapetus Curtis, 1834

Although highly abundant, the larvae of several species of *Agapetus,* widely distributed in the Mediterranean region, are not described (e.g., *A. incertulus* and *A. theichingeri*). Therefore, we only present here the species obtained from pupae or adults. It is interesting to point out that *Agapetus* sp. specimens found in the southern Mediterranean Basins appear to be more pollution tolerant that was expected from literature (González del Tánago & García de Jalón, 1984), specially to suspended solids, conductivity, nitrites and ammonium what could indicate that a mix of species is present (Bonada *et al.*, Chapter 8).

15- Agapetus fuscipes Curtis, 1834

MATERIAL STUDIED: 8P♂3P♀ (II, IV, V, VII), 1♂ (V)

Ter Basin: T3, T10
Besòs Basin: B12, B35
Llobregat Basin: L82
Foix Basin: F24

TAXONOMIC REMARKS

Vieira-Lanero (2000) found that most of the larvae of *A. fuscipes* collected in northwest of Spain lacked of setae in lateral position in the third abdominal segment. In our case, larvae collected where *A. fuscipes* pupae were found, present the typical seta pattern of *A. fuscipes* of 2-1-1 (first, second and third lateral setae of abdominal segments).

DISTRIBUTION AND ECOLOGY

Central and western European species. In the Iberian Peninsula *A. fuscipes* is widely distributed.

Although we have collected *A. fuscipes* in headwaters, it has also been found in other reaches, always with a high water quality (González del Tánago & García de Jalón, 1984; Wallace *et al.*, 1990). Therefore, it may be possible that *Agapetus* sp. found in southern basins belong to another species more tolerant to pollution. In some localities it has been found coexisting with *Synagapetus* sp.

16- Agapetus incertulus McLachlan, 1884

MATERIAL STUDIED: 1P♂ (VII), 3♂ (V, VII)

Segura Basin: SE16
Adra Basin: AD3, AD1

TAXONOMIC REMARKS

Larvae from this species remain undescribed. Larvae found where pupae were collected have a similar morphology to *A. fuscipes*, with an abdominal setae pattern of 2-1-1.

DISTRIBUTION AND ECOLOGY

This species is present in the Iberian Peninsula and North of Africa (González *et al.*, 1992). In the Iberian Peninsula is has been recorded mainly in southern basins.

It has been found in low altitude reaches (80-200 m) with a sedimentary and calcareous geology. It is able to tolerate high salinity and quite polluted waters, what would indicate that most of the *Agapetus* specimens found in southern areas may likely belong to *A. incertulus*.

Synagapetus McLachlan, 1879

This genus has been found in Ter, Tordera and Besòs basins coexisting with *Agapetus* sp. However, because a high number of larvae remain still undescribed and pupae or adults were unavailable in our samples, we were unable to identify larvae at species level.

Subfamily *Glossosomatinae* Wallengren, 1891

Glossosoma Curtis, 1834

17- Glossosoma* cf. *boltoni Curtis, 1834

MATERIAL STUDIED: 22L

Ter Basin: T1, T2, T7, T8, T9, T10, T11

TAXONOMIC REMARKS

From the species of the *Glossosoma* genus, larvae of *G. spoliatum* McLachlan, 1879 remains undescribed. It has been cited in north and northeast Spain (González *et al.*, 1992), where *G. boltoni* is also present. Our larvae look like *G. boltoni*, but we did not collect mature pupae to ensure our larval identifications.

DISTRIBUTION AND ECOLOGY

European species. In the Iberian Peninsula it has been found in northeastern basins.

In the Mediterranean sampled basins this species is confined to pristine headwaters in high-mountain rivers, but in some other European areas it has been collected in large rivers (Wallace *et al.*, 1990).

Family **HYDROPTILIDAE** Stephens, 1836

Subfamily *Hydroptilinae* Stephens, 1836

TRIBU Hydroptilini Stephens, 1836

Allotrichia McLachlan, 1880

18- Allotrichia pallicornis (Eaton, 1873)

MATERIAL STUDIED: 36L

Besòs Basin: B35
Mijares: MI8
Júcar Basin: JU11

TAXONOMIC REMARKS

Although no pupae or adults have been collected, our larvae fit under this species according to the redescription done by Vieira-Lanero (2000), with the presence of a dorsal sclerite in the IX abdominal segment.

DISTRIBUTION AND ECOLOGY

A. pallicornis is widely distributed in central and southern Europe, North of Africa and southwestern Asia (González *et al.*, 1992). In the Iberia Peninsula is widely distributed, although we only have collected it in northern and central basins.

This species can be found in different river reaches, preferring headwaters (see Vieira-Lanero, 2000). Accordingly, our larvae were found in headwaters and midstream reaches with different biological and riparian quality.

Hydroptila Dalman, 1819

Because in the Iberian Peninsula larvae of several species distributed in the Mediterranean coast remain undescribed (see González *et al.*, 1992), and the difficulties to distinguish the already described, we only present here results from pupae and adults collected.

19- Hydroptila* gr. *sparsa Curtis, 1834

MATERIAL STUDIED: 1P♂ (VIII)

Llobregat Basin: L68

TAXONOMIC REMARKS

The *sparsa*-group is highly variable (see Malicky, 1997). Our specimen is close to *H. angustata*.

DISTRIBUTION AND ECOLOGY

Species from *gr sparsa* have been found in Europe, North of Africa and southwestern Asia.

20- Hydroptila vectis Curtis, 1834

MATERIAL STUDIED: 8P♂2P♀ (II, IV, V, VIII, IX), 26♂10♀ (II, VIII, XI)

Tordera Basin: ToM9
Llobregat Basin: L60a, L61, L68
Foix Basin: F25
Almanzora Basin: AL4
Adra Basin: AD1, AD4
Guadalfeo Basin: GU6, GU7, GU9

DISTRIBUTION AND ECOLOGY

H. vectis is widely distributed around Europe, North of Africa and southwest Asia (see González *et al.*, 1992) as is in the Iberian Peninsula.

It is commonly present in different river reaches (Vieira-Lanero, 2000). In our basins *H. vectis* have been found mainly in midstream and lowland reaches under a wide range of environmental conditions, and very abundant when dense *Cladophora* masses were present (Stroot, 1984).

Oxyethira Eaton, 1873

This genus comprises 5 species in the Iberian Peninsula, and many difficulties are found to identify their larvae (see Vieira-Lanero, 2000). Specimens from this genus have found in reaches from Segura, Aguas and Almanzora basins with an altitude of 210-920m.

TRIBU Orthotrichiini Nielsen, 1948

Ithytrichia Eaton, 1873

Larva from this genus have been found in middle reaches from Turia, Júcar and Segura basins, but the lack of pupae or adults and the few information from larval stages (with some species undescribed or difficult to differentiate —Vieira-Lanero, 2000), does not allow us to achieve the species level with the material obtained.

Orthotrichia Eaton, 1873

21- Orthotrichia angustella (McLachlan, 1865)

MATERIAL STUDIED: 30L
Júcar Basin: JU2, JU6, JU8, JU9, JU13
Segura Basin: SE18

DISTRIBUTION AND ECOLOGY

European and North African species. In the Iberian Peninsula it is widely distributed, although we only have collected it in central-southern basins.

In rivers it has been found in midstream reaches at lower altitude (Décamps, 1967). In the Mediterranean area *O. angustella* has been found typically from calcareous/sedimentary middle reaches with a wide altitudinal range (160-1120 m).

Suborder ANNULIPALPIA

Superfamily PHILOPOTAMOIDEA Stephens, 1829

Family **PHILOPOTAMIDAE** Stephens, 1829

Subfamily *Philopotaminae* Stephens, 1829

Philopotamus Stephens, 1829

22- Philopotamus montanus (Donovan, 1813)

MATERIAL STUDIED: 344L, 3P♂1P♀ (IV, VII, VIII) 25♂ (III, IV, V)
Ter Basin: T1, T2, T4, T7, T10, T14, T15, T16, TM2, TM5
Tordera Basin: ToM12, ToM13, Tom14, Tom15
Besòs Basin: B35
Llobregat Basin: L56
Noguera Ribagorçana Basin: OUT0m
Segura Basin: SE4
Adra: AD5
Guadalfeo Basin: GU1, GU5, GU11

DISTRIBUTION AND ECOLOGY

European species. In the Iberian Peninsula it is widely distributed.

Accordingly to the literature (see Vieira-Lanero, 2000), as was the case in our samples, this species has been found mainly in headwaters with pristine conditions (see Bonada *et al.*, Chapter 8 and 9).

23- Philopotamus variegatus (Scopoli, 1763)

MATERIAL STUDIED: 2♂ (V, VI)
Ter Basin: T3, T17

DISTRIBUTION AND ECOLOGY

Central and southern European species. In the Iberian Peninsula it has been recorded in northern basins.

This species prefers headwaters of pristine rivers, similarly with *P. montanus* (see Vieira-Lanero, 2000).

Wormaldia McLachlan, 1865

The difficulty to distinguish larvae, and even adults, from this genus is notable. Therefore, only the adults found in the sampled areas (in Llobregat basin) are presented here, although larval specimens from the same genus were found in Tordera, Besòs, Turia and Júcar Basins.

24- Wormaldia triangulifera McLachlan, 1878

MATERIAL STUDIED: 1♂ (IV)
Llobregat Basin: L45

TAXONOMIC REMARKS

The specimen found belongs to the *triangulifera* sub-species.

DISTRIBUTION AND ECOLOGY

Southern European and Anatolian species. In the Iberian Peninsula it has been only recorded in eastern basins (González *et al.*, 1992).

The species has been recorded in headwater reaches between 300-1200 m of altitude (Décamps, 1967). The male collected in Llobregat basin was found in a small karstic stream located in a protected area (Sant Llorenç del Munt Natural Park).

25- Wormaldia saldetica Botosaneanu & González, 1984

MATERIAL STUDIED: 1P♂ (II)
Llobregat Basin: SC1

DISTRIBUTION AND ECOLOGY

This species is endemic from the Pyrenees.

Pupae from Llobregat basin were found in a small calcareous stream tributary of the Llobregat River, which has a good biological quality. The sampling site is not in the Pyrenees region itself but very close.

Subfamily *Chimarrinae* Rambur, 1842

Chimarra Stephens, 1829

26- Chimarra marginata (Linnaeus, 1767)

MATERIAL STUDIED: 786L, 1P♂ (X), 2♂ (V, VIII)

Llobregat Basin: L42, L44, L45, L60a, L61
Mijares Basin: MI5 MI6, MI9
Turia Basin: TU10, TU12
Júcar Basin: JU2, JU3, JU4, JU8, JU13, JU15, JU17, JU19
Segura Basin: SE5
Almanzora Basin: AL14, AL15
Aguas Basin: AG1, AG2, AG7
Adra Basin: AD3
Guadalfeo Basin: GU7, GU9

DISTRIBUTION AND ECOLOGY

Western European and North African species. In the Iberian Peninsula is widely distributed.

In sampled Mediterranean basins *C. marginata* were found in middle and lower parts of rivers with a calcareous/sedimentary geology, which is in accordance with records of many authors (see Vieira-Lanero, 2000). It is a species tolerant to conductivity, suspended solids and phosphates but sensitive to high values of ammonia (Bonada *et al.*, Chapter 8).

Superfamily HYDROPSYCHOIDEA Curtis, 1835

Family **HYDROPSYCHIDAE** Curtis, 1835

Subfamily *Hydropsychinae* Curtis, 1835

Hydropsyche Pictet, 1834

27- Hydropsyche* cf. *acinoxas Malicky, 1981

MATERIAL STUDIED: 4P♂ (IV, VIII)

Tordera Basin: ToM7, ToM8, ToM12
Besòs Basin: B8a

TAXONOMIC REMARKS

The pupae found fit quite well under *H. acinoxas*, although there are slight differences in the X segment difficult to evaluate because only the holotype is known (M.A. González pers. comm.). Larvae collected in these sampling sites and sclerites found from pupae, were very similar to *H. dinarica* and *H. instabilis*. The apotome is less quadrangular than *H. dinarica* but not as rounded as in *H. instabilis*. In the apotome a light posterior area V-shaped can be distinguish, more conspicuous than in *H. dinarica*.

DISTRIBUTION AND ECOLOGY

This species is endemic from the Iberian Peninsula. The holotype was found in Ter basin at 1000 m of altitude by Malicky (1981), and has been recorded in Montseny ranges also by Filbà (1986).

Pupae were found in small rivers at altitudes between 320-780 m. Sites from Tordera and Besòs basins had a very good biological and water quality, with high oxygen concentrations and low conductivity (≡100µS/cm).

28- Hydropsyche brevis Mosely, 1930

MATERIAL STUDIED: 58L

Mijares Basin: MI5, MI6, MI9
Turia Basin: TU9, TU10
Júcar Basin: JU2, JU4, JU5, JU12, JU13, JU17
Segura Basin: SE5, SE8, SE18

DISTRIBUTION AND ECOLOGY

Species confined to Iberian Peninsula and Pyrenees.

In the Mediterranean area we have found larvae mainly in central Spanish region in calcareous/sedimentary middle reaches. It is very sensitive to phosphates and ammonia compared with other Hydropsychids, but can tolerate a wide range of dissolved salts (Bonada *et al.*, Chapter 8).

29- Hydropsyche bulbifera McLachlan, 1878

MATERIAL STUDIED: 47L, 1P♂ (VII)

Besòs Basin: B22
Llobregat Basin: L44, L45
Mijares Basin: MI3, MI4, MI10
Segura Basin: SE1, SE2, SE5

DISTRIBUTION AND ECOLOGY

H. bulbifera is distributed around central and southern Europe and Anatolia. In the Iberian Peninsula it is widely distributed, but it lacks in the northwestern region. In the sampled Mediterranean basins it has been found mainly in northern and central basins, but reaching some southern areas.

This species has been recorded in permanent and temporary (García de Jalón, 1986) middle and lowland rivers (García de Jalón, 1982) with eutrophic waters (González del Tánago & García de Jalón, 1984). In the sampled Mediterranean area it has been also recorded in sites with a very good to fair biological quality.

30- Hydropsyche dinarica Marinkövic, 1979

MATERIAL STUDIED: 980L, 1P♂ (VII), 2♂ (VII)

Ter Basin: T2, T7, T8, T10, TM2. TM4, TM5
Tordera Basin: ToM15
Llobregat Basin: L56, L54

DISTRIBUTION AND ECOLOGY

West European species. In the Iberian Peninsula is widely distributed but more frequent in central and northern areas. In the Mediterranean sampled basins this species has been only collected in northern areas.

Until now, this species has been found in headwaters located at high altitude (Vieira-Lanero, 2000). In the Mediterranean basins, we found specimens in calcareous/siliceous high-mountain streams over 1200 m. It is a species sensitive to conductivity, suspended solids and ammonia, although it has been found in waters with higher phosphate concentrations than expected from literature (Basaguren & Orive, 1993).

31- Hydropsyche exocellata Dufőur, 1841

MATERIAL STUDIED: 3372L, 3P♂ (IV, VIII), 3♂ (IV)

Besòs Basin: B16, B12, B10, B17a, B25, B30, B35, B22
Llobregat Basin: L95 L42, L39, L100, L90, L91, L94, L101, L102, L68, L56, L64a, L60a, L60c, L38
Mijares Basin: MI6, MI3, MI1, MI8
Turia Basin: TU8, TU9, TU10, TU7, TU11, TU6, TU13
Júcar Basin: JU17, JU16, JU15, JU11, JU13, JU12, JU10, JU9, JU19, JU2, JU3, JU4, JU5
Segura Basin: SE6, SE10
Almanzora Basin: AL7
Adra Basin: ad1
Guadalfeo Basin: GU9, GU10

DISTRIBUTION AND ECOLOGY

West European species. In the Iberian Peninsula it is widely distributed.

It is very abundant in lowland reaches, or small rivers with polluted waters (see Vieira-Lanero, 2000). In the sampled basins, *H. exocellata* appears as the most tolerant hydropsychid to suspended solids, phosphates and ammonium, and it is present in sites with low riparian cover and fair to poor biological quality (Bonada *et al.*, Chapter 8).

32- Hydropsyche fontinalis Zamora-Muñoz *et al.*, 2002

MATERIAL STUDIED: 2L

Segura Basin: SE4

DISTRIBUTION AND ECOLOGY

Endemic species from the Iberian Peninsula (Zamora-Muñoz *et al.*, 2002).

Larvae are present in small calcareous permanent rivers with a very good water quality (Zamora-Muñoz *et al.*, 2002). The specimens found in Segura basins were located in reaches with these conditions at 1040 m of altitude.

33- Hydropsyche iberomaroccana González & Malicky, 1999

MATERIAL STUDIED: 13L, 1♂ (IV)

Adra Basin: AD3
Guadalfeo Basin: GU7, GU9

TAXONOMIC REMARKS

Larvae identified as *H. iberomaroccana* follow the distinctive head pattern found in Zamora-Muñoz *et al.* (1995) (= *H.* cf. *punica*).

DISTRIBUTION AND ECOLOGY

H. iberomaroccana is distributed in the Iberian Peninsula and North of Africa. In the Iberian Peninsula is has been collected only in southern areas, although difficulties are found to distinguish larvae of *H. incognita* from *H. iberomaroccana*. However, characteristic *H. iberomaroccana* larvae (as the ones discriminated in the step 17 by Zamora-Muñoz *et al.* —1995) were not found in northern basins.

The specimens found were located in reaches between an altitude of 200-540 m and with fair biological quality.

34- Hydropsyche incognita Pitsch, 1993

Because difficulties are found to distinguish larvae of *H. incognita* from *H. iberomaroccana,* both found in the Iberian Mediterranean area (Zamora-Muñoz *et al.*, 1995), only the records of *H. incognita* from pupae or adults are presented here. We have collected 1677 larvae that we have included, together under the category *H. gr pellucidula.*

MATERIAL STUDIED: 14P♂ (II, IV, VII, VIII, X), 9♂ (II, IV, V, IX)

Llobregat Basin: L44, L60c
Foix Basin: F25
Almanzora Basin: AL14
Aguas Basin: AG2, AG3, AG5
Adra Basin: AD2
Guadalfeo Basin: GU8, GU9

TAXONOMIC REMARKS

Recently, all the specimens recorded in the Iberian Peninsula as *H. pellucidula* (Curtis, 1834) have been classified as *H. incognita* because there are no evidences of presence of *H. pellucidula* in the area (Vieira-Lanero, 2000).

DISTRIBUTION AND ECOLOGY

Central and southwestern European species. In the Iberian Peninsula is widely distributed (Vieira-Lanero, 2000).

This species appear to tolerate wide ecological conditions (Vieira-Lanero, 2000). In the Mediterranean sampled rivers it has been found in midstream reaches wit fair biological and riparian quality.

35- Hydropsyche infernalis Schmid, 1952

MATERIAL STUDIED: 115L

Turia Basin: ?AF1
Segura Basin: SE3, SE7, SE16
Almanzora Basin: AL1, AL6, AL14
Aguas Basin: AG1, AG2
Adra Basin: AD3, AD4, AD5
Guadalfeo Basin: GU2, GU4, GU5, GU6, GU12, GU13

TAXONOMIC REMARKS

No pupae or adults have been collected in the area, but larvae have the same pattern as in Zamora-Muñoz *et al.* (1995), with a V-shape aboral spot in the apotome. However, most of the larvae collected in northwest of Spain where only *H. siltalai* is present, have a V-shape aboral spot (Vieira-Lanero, 2000) instead than U-shape. Therefore, in areas were both species have been collected, there may be difficulties in distinguishing both larval species. For example, because *H. infernalis* has been collected in southern and central Spain (see González *et al.*, 1992 and Zamora-Muñoz *et al.*, 1995), we can not ensure without pupae or adults that larvae collected from Turia Basin are truly *H. infernalis* or a variability of *H. siltalai*.

DISTRIBUTION AND ECOLOGY

Endemic species from the Iberian Peninsula, with a southern distribution.

This species has been associated to permanent siliceous (Ruiz *et al.*, 2001), calcareous and sedimentary-marls headwaters (Gallardo-Mayenco, 1994; Gallardo-Mayenco *et al.*, 1998). In the sampled Mediterranean area larvae were found in sedimentary midstream reaches with a wide range of conductivity and fair riparian and biological quality (Bonada *et al.*, Chapter 8 and 9).

36- Hydropsyche instabilis (Curtis, 1834)

MATERIAL STUDIED: 697L, 5P♂ (VII), 7♂ (II, VII, VIII)

Ter Basin: T10, T11, T12, TM4
Besòs Basin: B35
Llobregat Basin: L54, L56
Mijares Basin: MI4
Turia Basin: TU4, TU6
Júcar Basin: JU7, JU8
Segura Basin: SE1, SE3
Almanzora Basin: AL2, AL6, AL7
Adra Basin: AD4, AD5
Guadalfeo Basin: GU1, GU2, GU3, GU5, GU6, GU7, GU8, GU9, GU11, GU12, GU13, GU14, GU15, GU16

DISTRIBUTION AND ECOLOGY

European and Anatolian species. In the Iberian Peninsula is widely distributed.

H. instabilis has been found very abundant in clean headwaters (Vieira-Lanero, 2000). Our specimens have been collected in mountain siliceous and calcareous headwaters with a good biological quality. Although it appears to be more tolerant to environmental quality variables than *H. dinarica*, it is slightly more sensitive to phosphates.

37- Hydropsyche **gr.** *instabilis* (called *H. sp1*)

MATERIAL STUDIED: 93L, 2P♂ (VII, VIII)

Llobregat Basin: L44
Foix Basin: F25
Mijares Basin: MI3, MI7
Júcar Basin: JU1, JU7, JU15, JU17
Segura Basin: SE1

TAXONOMIC REMARKS

The pupa found is close to *H. infernalis* and *H. fontinalis* (M.A. González, pers. comm.). However, comparing our larvae and *H. fontinalis*, some differences can be established. Apotome is not as triangular as in *H. fontinalis*, with the posterior part not very pointed. There is always an oral light spot in the apotome more or less conspicuous and joined to lateral spots (see Figure 3). As in *H. fontinalis* in the center of the apotome a Y-shaped brown patch is distinguished. Ventrally, the brown areas of the head are triangular and smaller than in *H. fontinalis*. Finally, pronotum is not darker than meso and metanotum as happen in *H. fontinalis*. More pupae and adults should be collected to confirm the identity of these specimens.

Figure 3. Cephalic head from the *Hydropsyche gr instabilis* called *H. sp1*.

DISTRIBUTION AND ECOLOGY

It has been found in the northern basins in our sampled area. It is present in very low abundance and coexisting with *H.* gr. *pellucidula* in calcareous/sedimentary midstream reaches. Therefore, environmental tolerances of *H. sp1* are similar to *H.* gr. *pellucidula* although *H.* gr. *instabilis* appears in sites with slightly more riparian cover and biological quality. In the Chapters 8 and 9, *H. gr instabilis* has been coded as *H. sp1*.

38- Hydropsyche siltalai Döhler, 1963

MATERIAL STUDIED: 1876L, 2P♂ (VII, VIII)

Ter Basin: TM3
Tordera Basin: ToM8, ToM9, ToM11
Besòs Basin: B25, B7a, B28, B22, B35, B32, B36
Llobregat Basin: L42, L54, L60a
Júcar Basin: JU6, JU8
Segura Basin: SE5, SE18

TAXONOMIC REMARKS

In the northwest of Spain *H. siltalai* present a high variability in the head colour pattern with the light aboral spot from V-shape to U-shape (R. Vieira-Lanero, pers. comm.). Our specimens from northern Mediterranean basins have a U-shape spot, similar to other individuals from central Spain (see Zamora-Muñoz *et al.*, 1995).

DISTRIBUTION AND ECOLOGY

European and Anatolian species. In the Iberian Peninsula it is widely distributed. However, in the sampled Mediterranean basins has been found only in central and northern basins.

It may appear in all stream reaches although it prefers headwaters sites with mid to high altitudes (see Vieira-Lanero, 2000). In our sampled basins it has been found in calcareous/siliceous headwaters mountain streams with a well-developed riparian forest. González del Tánago & García de Jalón (1984) suggest that *H. siltalai* can tolerate some pollution what would agree with our results as this species appear to be slightly tolerant to suspended solids, phosphates and ammonium concentrations, but it is very sensitive to conductivity (Bonada *et al.*, Chapter 8).

39- Hydropsyche tibialis McLachlan, 1884

MATERIAL STUDIED: 7L
Guadalfeo Basin: GU1 GU11

DISTRIBUTION AND ECOLOGY

Endemic species from the Iberian Peninsula where it has found in western and southern areas.

This species has been recorded previously in mountain headwaters and clean reaches (Vieira-Lanero, 2000). In the Guadalfeo basins it has been found over 1500 m.

Cheumatopsyche Wallengren, 1891

40- Cheumatopsyche lepida (Pictet, 1834)

MATERIAL STUDIED: 2L, 1P♂ (X)
Llobregat Basin: L42
Júcar Basin: JU2, JU3, JU4, JU12, JU13
Segura Basin: SE5

DISTRIBUTION AND ECOLOGY

Species distributed around Europe and southwestern Asia. In the Iberian Peninsula us widely distributed, although in the sampled Mediterranean basins lacks in the most southern basins, probably because an appropriate habitat was unavailable.

C. lepida has been associated to middle and lowland reaches beeing present in clean waters although it can be also tolerant to some pollution (Vieira-Lanero, 2000). In Llobregat, Júcar and Segura rivers *C. lepida* was found in midstream reaches with a fair water quality where it is able to tolerate a wide range of phosphates concentration although it is quite sensitive to suspended solids, conductivity and ammonium.

Family **ECNOMIDAE** Ulmer, 1903

Ecnomus McLachlan, 1864

41- Ecnomus deceptor McLachlan, 1884

MATERIAL STUDIED: 1L, 1P♂ (VI)
Llobregat Basin: L77
Guadalquivir Basin: GE

DISTRIBUTION AND ECOLOGY

This species is known in the western Mediterranean area. In the Iberian Peninsula is widely distributed but is not present in northwestern area (Vieira-Lanero, 2000).

Larvae were found in midstream reaches at lower altitudes. It is a species able to tolerate high salinities (Stroot *et al.*, 1988) and it can also be present in quite eutrophic waters (González del Tánago & García de Jalón, 1984).

Family **PSYCHOMYIIDAE** Walker, 1852

Subfamily *Psychomyiinae* Walker, 1852

Psychomyia Latreille, 1829

42- Psychomyia pusilla (Fabricius, 1781)

MATERIAL STUDIED: 10L, 2♂ (VII)

Ter Basin: T21
Llobregat Basin: L42, L68
Júcar Basin: JU3, JU9

DISTRIBUTION AND ECOLOGY

Widely distributed in Europe, North of Africa and southwest Asia. In the Iberian Peninsula is widely distributed. However, in sampled Mediterranean basins this species were not found in southern basins.

This species prefers middle and lowland rivers, although it has been also found in small streams and middle reaches (Vieira-Lanero, 2000) with a calcareous geology (Edington & Alderson, 1973). Several authors observed that *P. pusilla* is able to tolerate some levels of eutrophication (González del Tánago & García de Jalón, 1984; Millet & Prat, 1984), what would agree with our records.

Lype McLachlan, 1878

43- Lype reducta (Hagen, 1868)

MATERIAL STUDIED: 5L, 2♂ (IV)

Besòs Basin: B25, B35
Segura Basin: SE2, SE18

DISTRIBUTION AND ECOLOGY

Species present in Europe, North of Africa and southwestern Asia. In the Iberian Peninsula it has been found in northern basins. We have recorded larvae from the Segura basin, what enlarge its distribution range.

Larvae are present in wide altitudinal range in small and large rivers (Vieira-Lanero, 2000). Specimens found in the Mediterranean basins were collected in rivers with an altitude from 250 m to over 1000 m.

Metalype Klapálek, 1898

44- Metalype fragilis (Pictet, 1834) (***Psychomyia fragilis***)

MATERIAL STUDIED: 8L

Segura Basin: SE1

DISTRIBUTION AND ECOLOGY

West European species. In the Iberian Peninsula has been recorded in northern and southern basins.

In the sampled Mediterranean area, *M. fragilis* is associated to calcareous midstream reaches at high altitude, in concordance to Edington & Alderson (1973).

Tinodes Curtis, 1834

Three species with undescribed larvae are recorded from south Spain (*T. algiricus* McLachlan, 1880, *T. maroccanus* Mosely, 1938 and *T. baenai*, González & Otero, 1984). This makes difficult the identifications of larvae from the Mediterranean Spanish Rivers, especially from southern basins. Identifications of specimens presented here were obtained from already know larvae and they should be taken with caution.

45- Tinodes assimilis McLachlan, 1865

MATERIAL STUDIED: 13L, 1♂ (VII)

Llobregat Basin: L56
Segura Basin: SE1
Almanzora Basin: AL6, AL7, AL11, AL14
Aguas Basin: AG2
Guadalfeo Basin: GU1

DISTRIBUTION AND ECOLOGY

West European species. In the Iberian Peninsula is widely distributed.

Larvae of the hygropetric *T. assimilis* has found in headwaters (Vieira-Lanero, 2000) reaching the 1800 m of altitude in some of our sampled sites.

46- Tinodes dives (Pictet, 1834)

MATERIAL STUDIED: 11L

Llobregat Basin: L44, L45, L56
Júcar Basin: JU6

DISTRIBUTION AND ECOLOGY

Central and southern European species. In the Iberia Peninsula it has been found in northeast basins. In the sampled Mediterranean area it also appears in more central basins.

This species has been found in mountain rivers at intermediate altitudes (Décamps, 1967). In the sampled basins, larvae we collected in calcareous headwater reaches with a good biological and riparian quality.

47- Tinodes maclachlani Kimmins, 1966

MATERIAL STUDIED: 2L

Llobregat Basin: L44, L45

DISTRIBUTION AND ECOLOGY

Western European species. In the Iberia Peninsula it has been found in northeast basins.

This hygropetric species (Edington & Alderson, 1973) have been collected in calcareous headwater reaches with a good biological and riparian quality.

48- Tinodes maculicornis (Pictet, 1834)

MATERIAL STUDIED: 7L

Besòs Basin: B36
Almanzora Basin: AL17

DISTRIBUTION AND ECOLOGY

Western European species. In the Iberia Peninsula it has been found in northern and southern basins.

In the Pyrenees this species has been collected in rivers with intermediate altitude (Décamps, 1967). In the sampled Mediterranean area, larvae were collected in headwater and midstream reaches with a good biological and riparian quality.

49- Tinodes waeneri (Linnaeus, 1758)

MATERIAL STUDIED: 34L, 1♂ (IV)

Besòs Basin: B28, B32, B35
Llobregat Basin: L60c, L102
Segura Basin: SE7

DISTRIBUTION AND ECOLOGY

European and North African species. In the Iberian Peninsula it is widely distributed. However, in sampled basins have been collected both in northern and southern areas.

This species prefers midstream reaches at medium to low altitudes (Vieira-Lanero, 2000). In the sampled Mediterranean area, *T. waeneri* has been found in stream reaches with very good to fair ecological quality.

Family **POLYCENTROPODIDAE** Ulmer, 1903

Subfamily *Polycentropodinae* Ulmer, 1903

Plectrocnemia Stephens, 1836

Specimens of *Plectrocnemia* were recorded in Besòs, Llobregat, Turia, Júcar, Segura, Adra and Guadalfeo basins. However, because the difficulty to differentiate larvae specially when they are not full growth (see Vieira-Lanero, 2000), we only present here records from pupae or adults.

50- Plectrocnemia geniculata McLachlan, 1871

MATERIAL STUDIED: 1♂ (IV)
Foix Basin: F7a

DISTRIBUTION AND ECOLOGY

Plectrocnemia geniculata is found in central and southern Europe and North of Africa. In the Iberian Peninsula is widely distributed but it lacks in northwestern region.

This species has been recorded in a wide range of altitudes (Décamps, 1967). In the Foix basin it has been found in headwaters with a very good ecological status.

51- Plectrocnemia laetabilis McLachlan, 1880

MATERIAL STUDIED: 1P♂ (V), 3♂ (VII, VIII)
Foix Basin: F33
Noguera Ribagorçana Basin: OUT0m, INLET

DISTRIBUTION AND ECOLOGY

Species present and widely distributed in the Iberian Peninsula, Pyrenees and North of Africa.

This species present a wide altitudinal range in headwaters of mountain rivers (Vieira-Lanero, 2000). The pupae and adults recorded by us were found in the inlet and outlet of a Pyrenean high mountain lake and in a small calcareous stream at middle altitude.

Polycentropus Curtis, 1835

52- Polycentropus flavomaculatus (Pictet, 1834)

MATERIAL STUDIED: 170L, 2P♂ (VIII), 8♂ (IV, V, VIII)
Ter Basin: T3, T10
Llobregat Basin: L38, L42, L44, L54, L56, L60a, L60c, L61, L64a, L68
Besòs Basin: B10, B22, B32, B35

DISTRIBUTION AND ECOLOGY

European and North African. In the Iberian Peninsula present a wide distribution. However, it only has been recorded in northern basins.

P. flavomaculatus is recognised to have a wide ecological range, beeing able to tolerate low oxygen concentration (see Vieira-Lanero, 2000). In the sampled Mediterranean area it has been found in calcareous/sedimentary midstream reaches with a fair water quality.

53- Polycentropus kingi McLachlan, 1881

MATERIAL STUDIED: 175L
Besòs Basin: B32
Júcar Basin: JU17
Segura Basin: SE1, SE2, SE3, SE4, SE7
Almanzora Basin: AL6, AL7, AL8, AL10, AL11
Aguas Basin: AG2, AG7
Guadalfeo Basin: GU5

DISTRIBUTION AND ECOLOGY

Western European and North African species. In the Iberian Peninsula have a wide distribution.

Some authors observed that *P. kingi* is present in headwaters and midstream reaches with a good water quality (see Vieira-Lanero, 2000), what would agree with our records. However, although it appears in sites with better biological quality than *P. flavomaculatus*, it can tolerate a wider range of suspended solids. Sometimes may coexist with *P. flavomaculatus*, although in few abundances (Edington & Hildrew, 1995).

Cyrnus Stephens, 1836

54- Cyrnus* cf. *montserrati González & Otero, 1983

MATERIAL STUDIED: 7L

Segura Basin: SE2

TAXONOMIC REMARKS

Although no pupae or adults have been found in the area and larvae of *C. montserrati* is not described, specimens found present a different head colour pattern compared with *C. cintranus* (R. Vieira-Lanero pers. comm.). Moreover, in the first abdominal segment, our individuals present 2 setae sa3 instead of 1 in *C. cintranus*. Consequently, we have called these specimens as *C.* cf. *montserrati.*

DISTRIBUTION AND ECOLOGY

This species is restricted to North of Africa and the Iberian Peninsula, where it has been recorded in southern areas.

The site where larvae were found is a calcareous and pristine headwater over 1000m of altitude.

Suborder INTEGRIPALPIA

Superfamily LIMNEPHILOIDEA Kolenati, 1848

Family **BRACHYCENTRIDAE** Ulmer, 1903

Brachycentrus Curtis**,** 1834

55- Brachycentrus (O.) maculatum (Fourcroy, 1785)

MATERIAL STUDIED: 8L

Llobregat Basin: L68
Guadalfeo Basin: GU3

DISTRIBUTION AND ECOLOGY

Central and western European species. In the Iberian Peninsula it is widely distributed. However, in the sampled basins it has been found only in two distant sites in the north and south.

This species is associated to mountain headwaters at medium altitudes (Vieira-Lanero, 2000). Our larvae were collected in headwaters and middle reaches with a fair to good water quality.

Micrasema McLachlan**,** 1876

56- Micrasema longulum McLachlan, 1876

MATERIAL STUDIED: 27L

Adra Basin: AD5
Guadalfeo Basin: GU1, GU2, GU5, GU15

DISTRIBUTION AND ECOLOGY

Central and western European species. In the Iberian Peninsula it is widely distributed. However, in the sampled Mediterranean basins only has been found in the most southern basins.

This species presents a wide altitudinal range (Vieira-Lanero, 2000). However, in the Mediterranean basins sampled, this species is typical from siliceous headwater over 1300m of altitude, what agree with studies performed in high mountainous areas (Décamps, 1967). It is very sensitive to environmental variables, although it can tolerate some phosphorous and be present in sites with low biological quality indexes.

57- Micrasema minimum McLachlan, 1876

MATERIAL STUDIED: 28L

Ter Basin: T3, T8, T10
Segura Basin: SE4

DISTRIBUTION AND ECOLOGY

Western European species. In the Iberian Peninsula it has been recorded only in northern basins. However, in the Mediterranean sampled basins some larvae were found in Segura basin, enlarging its distribution area.

M. minimum is characteristic from mountain headwaters at high altitudes (Vieira-Lanero, 2000). In the sampled basins, larvae were found in pristine calcareous and siliceous headwaters over 1000m of altitude.

58- Micrasema moestum (Hagen, 1868)

MATERIAL STUDIED: 212L

Segura Basin: SE1
Almanzora Basin: AL6, AL7, AL8
Adra Basin: AD5
Guadalfeo Basin: GU1, GU2, GU3, GU5, GU11, GU12, GU15

TAXONOMIC REMARKS

Some collected larvae display a pattern similar, although less conspicuous, to what Vieira-Lanero (2000) called *M.* gr. *moestum*.

DISTRIBUTION AND ECOLOGY

This species is distributed in southwestern Europe and North of Africa. In the Iberian Peninsula is has been found widely distributed. In sampled basins it was only collected in southern basins.

Micrasema moestum has been found in pristine headwaters (Vieira-Lanero, 2000). In the Mediterranean basins it seems to be highly sensitive to phosphates and ammonium (Bonada *et al.*, Chapter 8).

Family **LEPIDOSTOMATIDAE** Ulmer, 1903

Subfamily *Lepidostomatinae* Ulmer, 1903

Lepidostoma Rambur, 1842

59- Lepidostoma hirtum (Fabricius, 1775)

MATERIAL STUDIED: 14L

Tordera Basin: ToM6, ToM8, ToM10, ToM11

DISTRIBUTION AND ECOLOGY

European and Anatolian species. In the Iberian Peninsula it is widely distributed. In the sampled basins only has been collected in northern basins.

This species has been found in different rivers with high water quality (Vieira-Lanero, 2000). In our sampled basins, larvae were found in headwaters of forested areas.

Lasiocephala Costa, 1857

60- Lasiocephala basalis (Kolenati, 1848)

MATERIAL STUDIED: 417L, 13P♂10P♀ (VII), 12♂11♀ (V, VII)

Tordera Basin: ToM10, ToM11
Turia Basin: TU6
Júcar Basin: JU7, JU8
Segura Basin: SE1
Adra Basin: AD5
Guadalfeo Basin: GU1, GU2, GU3, GU5, GU9, GU11, GU12, GU13, GU14, GU15

DISTRIBUTION AND ECOLOGY

European species, lacking in Scandinavia. In the Iberian Peninsula it is widely distributed.

Lasiocephala basalis is a headwater species mainly located in a wide range of altitudes (Vieira-Lanero, 2000). In our sampled areas it appears associated to siliceous basins. It is a species sensitive to ammonium, phosphates and conductivity although it can tolerate a wide range of suspended solids.

Subfamily *Theliopsychinae* Weaver, 1993

Crunoecia McLachlan, 1876

61- Crunoecia irroata (Curtis, 1834)

MATERIAL STUDIED: 3L

Besòs Basin: B29

DISTRIBUTION AND ECOLOGY

Central and southern European species. In the Iberian Peninsula it is restricted to northern basins.

This species has been recorded at medium and higher altitudes (Vieira-Lanero, 2000). In sampled areas, it has been found in a mountainous and pristine area from Besòs basin.

Family **LIMNEPHILIDAE** Kolenati, 1848

Subfamily *Drusinae* Banks, 1916

Drusus Stephens, 1837

62- Drusus bolivari (McLachlan, 1880)

MATERIAL STUDIED: 17L

Segura Basin: SE1, SE4

DISTRIBUTION AND ECOLOGY

This species is distributed in the Iberian Peninsula, Pyrenees and France. In the Iberian Peninsula it has been recorded in northern, central and southern basins. In our sampled basins it has been only collected in Segura basin.

Vieira-Lanero (2000) found specimens from *D. bolivari* only in headwater reaches at high altitudes, which is coincident with our records, because the specimens from Segura basins were found in pristine and calcareous headwaters over 1000 m of altitude.

63- Drusus discolor (Rambur, 1842)

MATERIAL STUDIED: 5L

Ter Basin: T10, T18

Noguera Ribagorçana Basin: OUT200m

DISTRIBUTION AND ECOLOGY

Central and southern European species. In the Iberian Peninsula only has been recorded in the north.

This species prefers cold headwater reaches with high slopes (Vieira-Lanero, 2000). In our sampled basins it appears as a species with a narrow ecological profile and sensitive to pollution, present over 1200m of altitude.

64- Drusus rectus (McLachlan, 1868)

MATERIAL STUDIED: 167L, 1♂5♀ (VII)
Ter Basin: T10, T19
Noguera Ribagorçana Basin: OUT0m, OUT200m, INLET

TAXONOMIC REMARKS

Difficulties are found to distinguish *D. rectus* from *D. annulatus*. Both species have been recorded in Pyrenees as adults (see González *et al.*, 1992) but no larval keys are available to differentiate them. Hiley (1970), Szczęsny (1978), Wallace *et al.* (1990) and Waringer & Graf (1997) include only *D. annulatus*, whereas Décamps & Puyol (1975) only reported *D. rectus*. Because it was not possible to distinguish both species using literature, and no pupae or adults of *D. annulatus* were collected we have considered, provisionally, all specimens found as *D. rectus*.

DISTRIBUTION AND ECOLOGY

Southwestern European species. In the Iberian Peninsula it has been recorded in northern basins.

As *D. discolor*, this species were found in high-mountain pristine streams over 1200m, although it has been collected in lower altitudes in some Pyrenean areas (Décamps, 1967).

Anomalopterygella Fischer, 1966

65- Anomalopterygella chauviniana (Stein, 1874)

MATERIAL STUDIED: 27L, 1♂ (X)
Ter Basin: T12
Adra Basin: AD5
Guadalfeo Basin: GU1, GU15

DISTRIBUTION AND ECOLOGY

Southwestern Europe. In the Iberian Peninsula it is present mainly in northern basins, although it has been also recorded in some southern regions at high altitude.

A. chauviniana is a headwater species but may have a wide altitudinal range (Vieira-Lanero, 2000). In our sampled basins it has been mainly collected in siliceous headwaters. It appears as a sensitive species to ammonium and phosphates (Bonada *et al.*, Chapter 8).

Subfamily *Limnephilinae* Kolenati, 1848

TRIBU Limnephilini Kolenati, 1848

Limnephilus Leach, 1815

66- Limnephilus guadarramicus Schmid, 1955

MATERIAL STUDIED: 103L, 2♀ (IV)
Besòs Basin: B7, B24, B28

Llobregat Basin: L42, L44, L45, L60a, L61, L64a, L77
Mijares Basin: MI1, MI3, MI8, MI10
Turia Basin: TU1, TU5
Júcar Basin: JU6, JU8, JU17
Aguas Basin: AG5

TAXONOMIC REMARKS

This species present a high variability in the case morphology that may be entirely mineral (see original description in Vera, 1979) or made with twigs disposed tangentially (see Vieira-Lanero, 2000). In the sampled basins, we have found both cases types, although the woody one was more frequent.

DISTRIBUTION AND ECOLOGY

L. guadarramicus is an endemic species from the Iberian Peninsula, where it has been mainly recorded in northern regions. However, in the Mediterranean area some specimens have been found in central and some southern basins.

Larvae have been associated to wide ecological conditions, from small and big rivers to mountain lakes (Vieira-Lanero, 2000). In our basins it has been associated to headwaters of siliceous/calcareous basins. It is a very sensitive species to phosphates but can tolerate some ammonium and conductivity (Bonada *et al.*, Chapter 8). It was present at a wide range of riparian vegetation cover and fair biological quality.

67- Limnephilus lunatus Curtis, 1834

MATERIAL STUDIED: 3L, 2P♂ (IV)
Llobregat Basin: L64a, L77

DISTRIBUTION AND ECOLOGY

This species is distributed around Europe, North of Africa and southwestern Asia. In the Iberian Peninsula only has been recorded in northern basins.

L. lunatus has been recorded either in permanent and temporary rivers (Sommerhäuser *et al.*, 1997) under 1000 m of altitude (Décamps, 1967). In our samples, *L. lunatus* has been found in middle parts of rivers with fair water, biological and riparian quality.

Glyphotaelius Stephens, 1833

68- Glyphotaelius pellucidus (Retzius, 1783)

MATERIAL STUDIED: 20L, 2P♂1P♀ (II, IV), 4♂1♀ (II)
Ter Basin: SO
Besòs Basin: B7, B7a

TAXONOMIC REMARKS

Prat *et al.* (1983) recorded larvae of this species in the Besòs basin. Because no pupae or adults have been collected in Spain, Vieira-Lanero (2000), considered that the presence of *G. pellucidus* need to be confirmed. We reared larvae from Besòs basin, and we obtained several pupae and adults of *G. pellucidus* with the characteristic anterior wing morphology (see Schmid, 1952; Malicky, 1983). Moreover, larvae fitted very well according to Vieira-Lanero (2000) and Waringer & Graf (1997) keys, with 2 ventral setae of different colour in the first femur. Most of the specimens collected had the typical case made with round pieces of litter arranged in the characteristic way, although others used non-rounded pieces disposed longitudinally. On the other hand, some collected *Potamophylax* sp. (see later) had a case similar to the typical *Glyphotaelius*, what also have been observed by other authors (e.g., Wallace *et al.*, 1990, Vieira-Lanero, 2000).

DISTRIBUTION AND ECOLOGY

European and Siberian species. In the Iberian Peninsula it has been only recorded in northeastern basins.

Some studies in central Europe areas reported that this species is found in rivers with thick layers of organic detritus in permanent and temporary rivers (Wallace *et al.*, 1990; Sommerhäuser *et al.*, 1997). In our basins, *G. pellucidus* has been found exclusively in headwaters of temporary rivers, having a flight period earlier than in more temperate climates (Sommerhäuser *et al.*, 1997). It is associated to a high chemical and biological quality, and a well-developed riparian forest with alders (*Alnus glutinosa)* and hazelnut trees (*Corylus avellana*).

TRIBU Chaetopterygini Hagen, 1858

Chaetopteryx Stephens, 1829

Larvae of *Chaetopteryx* have been recorded in Ter, Besòs, Llobregat, Turia, Júcar, Segura and Guadalfeo basins. Because the difficulties to identify larvae at species level species, and only records from pupae and adults are presented here.

69- Chaetopteryx villosa (Fabricius, 1798)

MATERIAL STUDIED: 1♀ (X)

Ter Basin: T10

DISTRIBUTION AND ECOLOGY

European species. In the Iberian Peninsula it is distributed in northern basins.

In our case, the adult were found in a headwater stream with pristine conditions at an altitude over 1100 m.

TRIBU Stenophylacini Schmid, 1955

Potamophylax Wallengren, 1891

70- Potamophylax cingulatus (Stephens, 1837)

MATERIAL STUDIED: 194L, 5P♂2P♀ (VIII), 1♂2♀ (VIII)

Ter Basin: TM1, TM2, TM3, TM4, T8, T9, T10, T11
Tordera Basin: ToM13, ToM15
Besòs Basin: B35
Llobregat Basin: L54, L56
Noguera Ribagorçana Basin: INLET
Júcar Basin: JU1

DISTRIBUTION AND ECOLOGY

European species. In the Iberian Peninsula it is present in northern basins.

This species has been found in permanent headwater reaches (Sommerhäuser *et al.*, 1997) without presenting a summer diapauses (Malicky, 1987). *P. cingulatus* has been found coexisting with *P. latipennis* but reaching higher altitudes (Vieira-Lanero, 2000). In sampled area it is an intolerant species, especially to conductivity, suspended solids and phosphates (Bonada *et al.*, Chapter 8).

71- Potamophylax latipennis (Curtis, 1834)

MATERIAL STUDIED: 257L, 8P♂ 12P♀ (VIII), 10♂3♀ (II, VII, VIII, X)

Ter Basin: T7, T9, T10, T12, TM1, TM3, TM4, TM5
Tordera Basin: ToM7, ToM8
Besòs Basin: B8a, B29, B35, B36
Llobregat Basin: L54, L56, L60a
Adra Basin: AD5
Guadalfeo Basin: GU1, GU11, GU15

DISTRIBUTION AND ECOLOGY

This species is distributed around Europe, Siberia and Anatolia. In the Iberian Peninsula it is distributed in northern basins, although it has been recorded in some southern areas (see González *et al.*, 1992).

Similarly to *P. cingulatus*, this species is present in mountain headwater reaches. *P. latipennis* is more intolerant to environmental quality variables than the former species, especially to ammonium concentration.

Halesus Stephens, 1836

72- Halesus digitatus (Schrank, 1781)

MATERIAL STUDIED: 51L, 2♂ (VII, X)

Ter Basin: T8, T10, T12
Besòs Basin: B35
Llobregat Basin: L44, L54, L68
Noguera Ribagorçana Basin: OUT200m

DISTRIBUTION AND ECOLOGY

This species is distributed around Europe reaching Iran. In the Iberian Peninsula only has been recorded in northeastern basins, as has been in our case.

In other European areas with karstic formations, *H. digitatus* has been found a dominant species in both temporary (Kiss, 1984) and permanent streams (Sommerhäuser *et al.*, 1997). In our sampled streams, specimens were found in calcareous/siliceous headwaters located in a wide altitudinal range.

73- Halesus radiatus (Curtis, 1834)

MATERIAL STUDIED: 103L

Ter Basin: T7, TM1, TM4, TM5

Tordera Basin: ToM6, ToM7, ToM8, ToM10, ToM11, ToM12, ToM15
Besòs Basin: B7a, B8a, B32, B35, B36
Llobregat Basin: L44, L56, L68
Mijares Basin: MI7
Turia Basin: TU1, TU2, TU4
Júcar Basin: JU1, JU7, JU8

DISTRIBUTION AND ECOLOGY

European species. In the Iberian Peninsula it is distributed in central and northern basins, as in our samples.

This species has a wide ecological range beeing able to survive in headwater and middle reaches (Vieira-Lanero, 2000) with a permanent flow (Sommerhäuser *et al.*, 1997). In our samples it has been found in headwaters at high to medium altitude. In these conditions, larvae appear sensitive to phosphates, suspended solids and conductivity but may be present in low ammonium concentrations (Bonada *et al.*, Chapter 8).

74- Halesus tessellatus (Curtis, 1834)

MATERIAL STUDIED: 142L

Besòs Basin: B35
Turia Basin: TU1, TU2
Júcar Basin: JU7, JU8
Segura Basin: SE1, SE3, SE4
Adra Basin: AD5
Guadalfeo Basin: GU1, GU5, GU11, GU12, GU15

TAXONOMIC REMARKS

Although we did not find pupae or adults from *H. tessellatus* in the sampled basins, Zamora-Muñoz & Alba-Tercedor (1995) indicated the presence of this species in the Iberian Peninsula. The larvae examined correspond to this species according to Panzeböck & Waringer (1997), even assuming difficulties found to differentiate *H. tessellatus* from *H. digitatus*. Pupae and adult material should be analyzed to confirm the presence of *H. tessellatus* in northern basins, where we only found larval specimens.

DISTRIBUTION AND ECOLOGY

European species with some records in Siberia (Lepneva, 1971). In the Iberian Peninsula it has been recorded until now only in southern areas.

In our sampled basins, *H. tessellatus* has been collected in mountain pristine headwaters with a low conductivity (Zamora-Muñoz & Alba-Tercedor, 1995), but it has been collected in high saline water in central Europe (Botosaneanu & Malicky, 1978). In the Mediterranean sampled basins it appears to be more sensitive to ammonium, phosphates, suspended solids and conductivity than *H. radiatus* (Bonada *et al.*, Chapter 8).

Stenophylax Kolenati, 1848

Many difficulties are found to identify *Stenophylax* species in the Iberian Peninsula, because not all the recorded species have described larvae. Therefore, we only include here few pupae or adults collected in the studied area. However, larvae of this genus have been found in several temporary streams in Besòs, Júcar, Segura, Almanzora and Guadalfeo basins.

75*- *Stenophylax spanioli Schmid, 1957

MATERIAL STUDIED: 2P♂ (X), 1♂ (X)
Ter Basin: T10

TAXONOMIC REMARKS

Larvae from this species remain undescribed. In the sclerites of pupae we found setae insertions in the anterior sides of meso and meta-femora, what would indicate that species is close to *S. permistus* according to Vieira-Lanero (2000).

DISTRIBUTION AND ECOLOGY

This species is distributed in the Iberian Peninsula, North of Africa and Pyrenees.

Pupae and adults were found in a siliceous and pristine headwater permanent stream at high altitude.

Mesophylax McLachlan, 1882

76*- *Mesophylax aspersus (Rambur, 1842)

MATERIAL STUDIED: 316L, 11P♂1P♀ (II, III, IV, V, VII), 48♂14♀ (II, IV, V, XI)
Besòs Basin: B7a, B12, B22, B24, B28, B32
Llobregat Basin: L42, L45, L60c
Foix Basin: F4, F7, F7a, F16, F28
Mijares Basin: MI1, MI3, MI7
Turia Basin: TU3, TU7
Júcar Basin: JU5
Segura Basin: SE3, SE8, SE10, SE13, SE15, SE16
Almanzora Basin: AL1, AL2, AL3, AL4, AL5, AL10, AL11, AL14
Adra Basin: AD4
Guadalfeo Basin: GU5, GU6, GU7

TAXONOMIC REMARKS

Although Malicky (1998) considered that all *Mesophylax* species from the Iberian Peninsula are *M. aspersus*, the species *M. impunctatus* has been recorded by other authors (see González *et al.*, 1992). According to Wallace at al. (1990) and Waringer & Graf (1997), both species can be clearly differentiated by the number of ventral setae in the first femur: 2 in *M. impunctatus* and 3 in *M. aspersus*. We have reared several larvae in the lab with 2 ventral setae in the first leg, and adults of only *M. aspersus* were obtained (n=62). All larvae collected in the field that were not reared presented 2 setae in both legs except in three specimens, with 2 setae in one femur and 3 in the other. Therefore, we consider that this character is no useful to distinguish both species in the Iberian Peninsula. It might be possible that differences between larvae of two species are not clear, because taxonomy of adults is not either (M.A. González, pers. comm.).

DISTRIBUTION AND ECOLOGY

This species is present in Western Europe, Mediterranean region, Madeira, Canary Islands and southwestern Asia (until Cachemira). In the Iberian Peninsula is widely distributed.

Although *M. aspersus* have been collected in permanent headwaters or midstream reaches, it is more characteristic from temporary rivers. It is well known its ability to survive under a drought period adapting its life-cycle (e.g., Bouvet, 1974; Bournaud, 1971). In that sense, we observed (in lab rearing) that even when a drought period is created suddenly, mature pupae emerge very quick. On the other hand, larvae are able to tolerate a wide range of conductivity, suspended solid and phosphates (and even ammonium), beeing the Limnephilid less sensitive to pollution (Bonada *et al.*, Chapter 8). It has been found in reaches with good to fair riparian and biological quality.

Allogamus Schmid, 1955

77- Allogamus auricollis (Pictet, 1834)

MATERIAL STUDIED: 13L,
Ter Basin: T1, T2, T12
Llobregat Basin: L44

TAXONOMIC REMARKS

Some specimens found in Ter basins present very long mineral cases, approximately the double of larval size.

DISTRIBUTION AND ECOLOGY

Central and western European species. In the Iberian Peninsula only has been found in northeast basins and some western areas.

A. auricollis has been recorded mainly in headwaters reaches in calcareous and siliceous alpine regions (Bautista, 1980; Graf *et al.*, 1992). Although it has been considered a species able to tolerate some water pollution (e.g., Bautista, 1980), other studies have associated it with pristine alpine rivers (Graf *et al.*, 1992). Our records are found in headwater reaches with very good biological quality.

78- Allogamus mortoni (Navás, 1907)

MATERIAL STUDIED: 1P♂ (XI)
Almanzora Basin: AL6

TAXONOMIC REMARKS

Allogamus mortoni (Navás, 1907) has been recorded by other authors in southern Spain (C. Zamora-Muñoz, pers. comm.) but larvae are still undescribed. From sites were only *A. mortoni* is present (collected by C. Zamora-Muñoz), larvae present also a light band in the anterior part of pronotum as in *A. ligonifer*. In southern basins we have collected 45 larvae of A*llogamus* and most of them present this colour pattern in the pronotum. Therefore, pupae or adults are required to confirm their identity.

DISTRIBUTION AND ECOLOGY

Species only present in the Iberian Peninsula where has been found in southern Spain and Portugal

The collected pupa from *A. mortoni* has been found in a karstic river at medium altitude, but other authors have collected it in siliceous waters of southern Spain (Ruiz *et al.*, 2001).

Family **UENOIDAE** Iwata, 1927

Subfamily *Thremmatinae* Martynov, 1935

Thremma McLachlan, 1876

79- Thremma gallicum McLachlan, 1880

MATERIAL STUDIED: 9L

Noguera Ribagorçana Basin: OUT0m, OUT200m

DISTRIBUTION AND ECOLOGY

Southwestern European species. In the Iberian Peninsula it has been found only in the north.

Larvae have been found in siliceous and pristine mountain reaches at medium and higher altitude (Vieira-Lanero, 2000), what agrees with our records.

Family **GOERIDAE** Ulmer, 1903

Subfamily *Goerinae* Ulmer, 1903

Silo Curtis, 1830

80- Silo graellsii Pictet, 1865

MATERIAL STUDIED: 25L

Ter Basin: T1, T8, T11, T12, TM2, TM4, TM5
Tordera Basin: ToM7

DISTRIBUTION AND ECOLOGY

Southwestern European species. In the Iberian Peninsula it has been found in northern basins.

S. graellsii is present in pristine mountain reaches at medium and high altitudes (Vieira-Lanero, 2000), which is coincident with our records.

Superfamily LEPTOCEROIDEA Leach, 1815

Family **LEPTOCERIDAE** Leach, 1815

Subfamily *Leptocerinae* Leach, 1815

TRIBU Athripsodini Morse & Wallace, 1976

Athripsodes Billberg, 1820

Several species with distribution around Mediterranean area remain undescribed (e.g. *A. taounate*). Therefore, although larvae from this genus have been found in Almanzora, Aguas, Adra and Guadalfeo basins, only pupae or adults collected are presented here.

81- Athripsodes albifrons (Linnaeus, 1758)

MATERIAL STUDIED: 1P♀ (VII)
Guadalfeo Basin: GU1

DISTRIBUTION AND ECOLOGY

European species. In the Iberian Peninsula it is widely distributed.

Larvae have been found in streams at lower altitudes (Vieira-Lanero, 2000) although our specimen was found at 1860 m of altitude in the Guadalfeo basin.

Ceraclea Stephens, 1829

82- Ceraclea sobradieli (Navás, 1917)

MATERIAL STUDIED: 2L
Júcar Basin: JU10

DISTRIBUTION AND ECOLOGY

Species only present in the Pyrenees and Iberian Peninsula where it is widely distributed.

In our sampled basins this species was present in a calcareous and sedimentary lowland river, what agrees with other studies (Terra & Molles, 1987). In Júcar basins, larvae are present in reaches with a moderate pollution.

TRIBU Mysacidini Burmeister, 1839

Mystacides Berthold, 1827

83- Mystacides azurea (Linnaeus, 1761)

MATERIAL STUDIED: 62L
Tordera Basin: ToM8, ToM9, ToM11, ToM12
Besòs basin: B24, B32, B35
Llobregat Basin: L44, L45, L61, L68
Mijares Basin: MI5

Turia Basin: TU10
Júcar Basin: JU2, JU10
Segura Basin: SE2, SE18

DISTRIBUTION AND ECOLOGY

European species. In the Iberian Peninsula it is widely distributed.

This species has been found in wide ecological conditions, from lakes to stream reaches at different altitudes (Vieira-Lanero, 2000). In the sampled basins, larvae were found in headwaters and midstream reaches with low conductivity, suspended solids, phosphates and ammonium, and a higher riparian vegetation quality that other Leptoceridae. However, González del Tánago & García de Jalón (1984) considered this species able to tolerate eutrophy.

TRIBU Oecetini Silfvenius, 1905

Oecetis McLachlan, 1877

We have found larvae of *Oecetis* in Segura basin, although it was impossible to determine them because larvae of some species recorded near the Mediterranean area remain still undescribed (e.g., *O. grazalemae*).

TRIBU Setodini Morse, 1981

Setodes Rambur, 1842

84- Setodes argentipunctellus McLachlan, 1877

MATERIAL STUDIED: 112L, 1P♀ (X)
Turia Basin: TU12
Júcar Basin: JU2, JU6
Segura Basin: SE2, SE4, SE16
Almanzora Basin: AL2, AL6
Aguas Basin: AG1, AG2
Adra Basin: AD1, AD3
Guadalfeo Basin: GU16

DISTRIBUTION AND ECOLOGY

This species is preset in Western Europe and North of Africa. In the Iberian Peninsula it is widely distributed, although we did not find it in sampled northern basins.

Larvae have been collected in midstream and lowland reaches at low altitudes (Vieira-Lanero, 200), what agree with our records. According to González del Tánago & García de Jalón (1984) larvae is present in eutrophic conditions. However, in the sampled rivers *S. argentipunctellus* appears to be very sensitive to ammonium, phosphates and suspended solids but tolerant to a wide range of conductivity (Bonada *et al.*, Chapter 8).

TRIBU Triaenodini Morse, 1981

Adicella McLachlan, 1877

85- Adicella reducta (McLachlan, 1865)

MATERIAL STUDIED: 5L, 1♀ (VII)
Tordera Basin: ToM10, ToM12
Besòs Basin: B29
Guadalfeo Basin: GU1, GU1

DISTRIBUTION AND ECOLOGY

European species. In the Iberian Peninsula it is widely distributed. In the sampled basins only has been found in the most northern and southern basins.

Larvae appear in a wide ecological conditions but very sensitive to pollution (Vieira-Lanero, 2000). In our samples it has been found in headwaters reaches in forested and preserved areas.

Family **CALAMOCERATIDAE** Ulmer, 1905

Subfamily *Calamoceratinae* Ulmer, 1905

Calamoceras Brauer, 1865

86- Calamoceras marsupus Brauer, 1865

MATERIAL STUDIED: 2L
Segura Basin: SE1, SE2

DISTRIBUTION AND ECOLOGY

Southwestern European species. In the Iberian Peninsula it is widely distributed.

Larvae have been found in different ecological conditions preferring non-polluted waters (Vieira-Lanero, 2000). In our sampled basins, specimens were found in a stream over 1000m of altitude with a very good biological and riparian quality.

Family **ODONTOCERIDAE** Wallengren, 1891

Subfamily *Odontocerinae* Wallengren, 1891

Odontocerum Leach, 1815

87- Odontocerum albicorne (Scopoli, 1763)

MATERIAL STUDIED: 201L, 3P♂ (IV, VI), 11♂ (VII, VIII)
Ter Basin: T4, T7, T8, T10, T11, TM2, TM3, TM4, TM5

Tordera Basin: ToM6, ToM7, ToM8, ToM11, ToM12, ToM13, ToM14, ToM15
Besòs Basin: B8a, B12, B32, B35
Llobregat Basin: L54, L56, L60a

DISTRIBUTION AND ECOLOGY

European species. In the Iberian Peninsula it has been found only in northern basins (González *et al.*, 1992).

O. albicorne has been recorded in headwaters and middle reaches by different authors (see Vieira-Lanero, 2000). In our sampled basins, this species has been found in similar part of rivers but always with a high biological and riparian quality. *O. albicorne* appears sensitive to conductivity and ammonium (Bonada *et al.*, Chapter 8).

Superfamily SERICOSTOMATOIDEA Stephens, 1836

Family **SERICOSTOMATIDAE** Stephens, 1836

Sericostoma Latreille, 1825

Difficulties are found to distinguish larvae from *Sericostoma*. Therefore, we only present here identifications from pupae or adults. A revision of the adults found in the Iberian Peninsula is needed because their morphological variability (M. A. González pers. comm.).

88- Sericostoma pyrenaicum Pictet, 1865

MATERIAL STUDIED: 3P♂ (VII), 2♂ (IV)
Besòs Basin: B32
Llobregat Basin: L54
Foix Basin: F11
Segura Basin: SE1

DISTRIBUTION AND ECOLOGY

Southwestern European species. In the Iberian Peninsula it has been found only in the north.

As in our case, this species has been recorded in headwaters with a wide altitudinal range, sometimes coexisting with *S. vittatum* (Vieira-Lanero, 2000).

89- Sericostoma vittatum Rambur, 1842

MATERIAL STUDIED: 1♂ (VII)
Adra Basin: AD5

DISTRIBUTION AND ECOLOGY

This species is endemic from the Iberian Peninsula, where it is widely distributed.

As in our case, *S. vittatum* has been found together with *S. pyrenaicum* in headwater reaches at medium and high altitudes (Vieira-Lanero, 2000).

Schizopelex McLachlan, 1876

Because *S. furcipera* remains still undescribed we only present here identifications from pupae and adult specimens from this genus. No larvae were collected from this genus using the features present in Vieira-Lanero (2000) to distinguish *Schizopelex* from *Sericostoma*.

90- Schizopelex furcipera McLachlan, 1880

MATERIAL STUDIED: 1P♂ (VIII), 1♂ (VII)
Ter Basin: T20
Tordera Basin: ToM7

DISTRIBUTION AND ECOLOGY

S. furcipera is present in Pyrenees and Iberian Peninsula, where has been recorded only in the north.

In the Pyrenees this species has been found under 1560m of altitude (Décamps, 1967). In the sampled areas, pupae and adults were found in pristine headwaters of forested areas at medium and high altitudes.

Family **BERAEIDAE** Wallengren, 1891

Beraea Stephens, 1833

91- Beraea maurus (Curtis, 1834)

MATERIAL STUDIED: 2L
Besòs Basin: B29
Llobregat Basin: L44

DISTRIBUTION AND ECOLOGY

European species. In the Iberian Peninsula is distributed in ther north.

B. maurus has been collected in small headwater streams with mosses and leaves (Lepneva, 1971; Wallace *et al.*, 1990) located at high altitudes (Décamps, 1967). In the sampled sites, larvae were found in pristine headwaters at mid altitudes.

DISCUSSION

Mediterranean climate areas have been considered by several authors as regions that shelter high diversity (e.g., Raven 1973; Deacon, 1983), comparing with other more temperate faunas. Reasons for that may be related to the climatic features that provide intermediate levels of disturbance, that according several authors may imply high species richness (e.g., Minshall, 1988; Sousa, 1984). Moreover, besides these climatic features, historical processes have been very important to explain the high plant and animal richness present in the Mediterranean basins area (see Bonada *et al.*, Chapter 3). In fact, some caddisfly species have been evolved in these areas, as those belonging to the *Stenophylax* group (Malicky, 1987). That is the case of *Mesophylax aspersus* that was one of the most abundant and frequent species in sampled basins because its ability to avoid dried periods by behavioral adaptations (e.g., Bouvet, 1974; Bournaud, 1971).

However, and according to the known records of the caddisflies in the Iberian Peninsula made by González *et al.* (1987), the Mediterranean area is poorer in species than other more temperate areas in the north and specially the northwest of Spain. This phenomenon has been related to historical factors but the major number of studies performed in northern areas in the Iberian Peninsula mades this statement not definitive (González *et al.*, 1987). Although not all the Mediterranean basins were sampled in the present study and even though not all the specimens were able to be identified using larvae (e.g., *Hydroptila*, *Stenophylax* ...), we collected a total of 91 species. This represents around 27% of the species recorded in the Iberian Peninsula. The maximum diversity of caddisflies in the sampled area was found in areas with high-mountain influences (e.g., rivers from Pyrenees, Montseny and Sierra Nevada ranges) or regions where a mixing of northern and southern species distributions occurs (e.g., in Segura basin). Besides this, Mediterranean rivers from central and some southeastern areas (e.g., rivers from Almería) present a depauperate caddisfly fauna (see Bonada *et al.*, Chapter 8) what can be related to the lack of more extensive studies in the area (González *et al.*, 1987), but specially to the harshness of the climatic features specially in the arid southern areas where the human alteration present all along the Mediterranean coast is even higher.

A representation of groups of species according to their distribution areas are presented in Figure 4. The sampling sites have been divided in three groups, the northern, central and southern basins. According to the information obtained from literature species have been grouped as European (including species present in Pyrenees and Iberian Peninsula), Iberian-North African and endemic species. Overall, most of the recorded caddisflies collected here present a European distribution, what has been pointed out by González *et al.* (1987). European species are dominant in northern and central basins and in contrast, southern basins present a higher number of species distributed also in North Africa. Southern basins present the highest proportion of endemic species, with a mix of species widely distributed around the Iberian Peninsula and those exclusive from the Baetic-Rift area. Our results emphasized the importance of southern basins as a speciation area for several groups of invertebrates (Ruiz *et al.*, 2001), which was independent from those that took place in the northwestern areas of the Hesperic Massif (González *et al.*, 1987).

A total of 12499 larvae, 177 pupae and 261 adults from 169 sites have been identified in our study. From the records presented here we extend the distribution areas of some species, confirm the presence of some others and point out several relevant taxonomic information for further studies. However, more investigations should be performed to ensure the identity of several species (e.g., *H.* gr. *instabilis* called *H. sp1*) and to describe larvae specimens of some species (e.g., *H. acinoxas, A. incertulus, A. mortoni*).

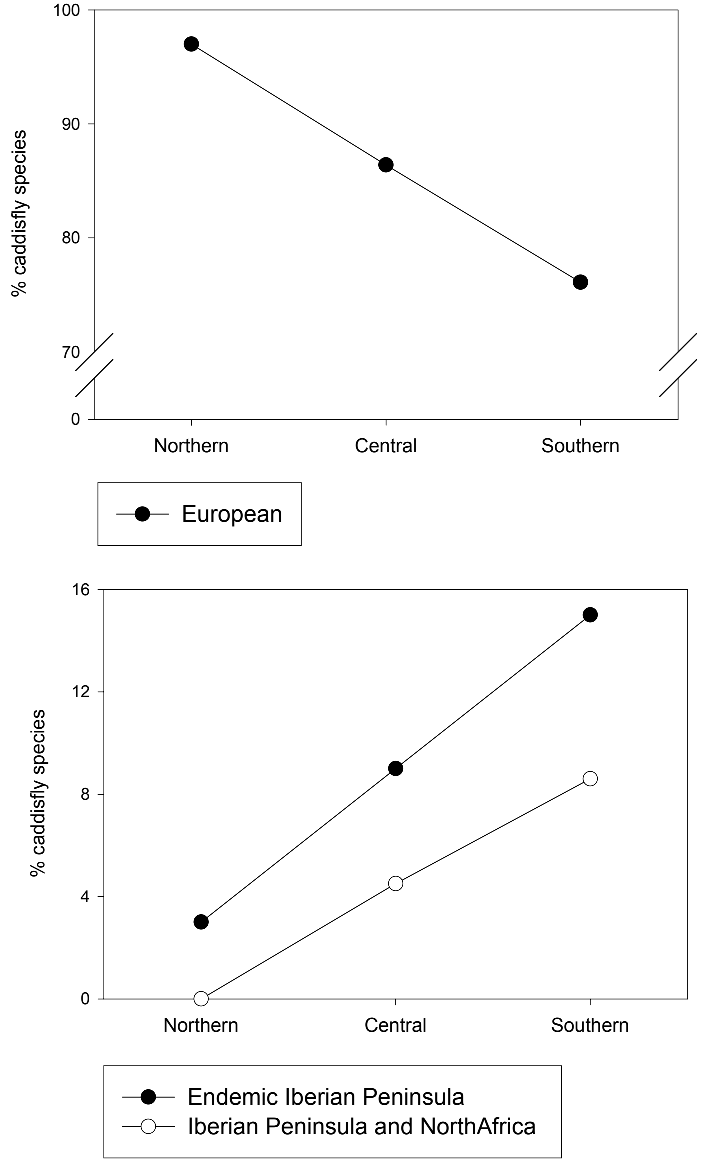

Figure 4. Proportion of European, Iberian-North African and endemic species for each group of basins. Northern basins include Ter, Tordera, Besòs, Llobregat, Foix and Noguera Ribagorçana. Central basins include Mijares, Turia and Júcar basins. Southern basins include Segura, Almanzora, Aguas, Adra, Guadalfeo and Guadalquivir.

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Annex 1. Sampling sites where Trichoptera has been found. The code used in the text, UTM coordinates, the river name and the altitude are shown.

Site code	X_UTM	Y_UTM	Stream/River	Altitude (m.)
TER BASIN				
T1	4416	46940	Ter	1440
T2	4425	46934	Ter/Carboners	1380
T3	4428	46874	Ter	1080
T4	4448	46862	Ter	1000
T5	4234	46790	Garfull	1020
T7	4499	46926	Ritort	1220
T8	4506	46919	Ritort	1200
T9	4508	46910	Ritort	1160
T10	4513	46908	Fabert	1180
T11	4517	46888	Torrent de la Ginestosa	1080
T12	4484	46853	Ritort	960
T14	4476	46927	Torrent de la Casassa	1420
T15	4463	46869	Feitús	920
T16	4388	46703	La Tolosa	920
T17	4266	46851	Rigart	1060
T18	4295	46918	Fontalba	2060
T19	4303	46945	Torrent de Finestrelles	1980
T20	4419	46900	Ter	1180
T21	4515	46887	Ritort	1060
SO	4355	46648	Riera de la Solana	640
TM1	4428	46300	Torrent de Valldoriola	740
TM2	4466	46333	Riera de la Sala	680
TM3	4477	46336	Riera Major	700
TM4	4493	46320	Torrent de Collpregon	800
TM5	4522	46341	Riera d'Espinelves	760
TORDERA BASIN				
ToM6	4552	46306	Riera d'Arbúcies	480
ToM7	4575	46293	Sot del Clot	460
ToM8	4582	46299	Riera d'Arbúcies	360
ToM9	4631	46270	Riera d'Arbúcies	200
ToM10	4481	46249	Riera de la Castanya	480
ToM11	4484	46248	Riera de Sant Marçal	460
ToM12	4512	46265	Riera de Sant Marçal	780
ToM13	4529	46229	Sot de l'Infern	720
ToM14	4545	46258	Riera de Santa Fe	1220
ToM15	4555	46251	Riera de Santa Fe	1140
RIBERA RIBAGORÇANA BASIN				
INLET	3183	47234	Inlet to Lac Redon	2240
OUT0m	3179	47232	Barranc de Lac Redon	2220
OUT200m	3170	47231	Barranc de Lac Redon	2200

Site code	X_UTM	Y_UTM	Stream/River	Altitude (m.)
BESÒS BASIN				
B8a	4458	46178	Riera de Cànoves	320
B10	4400	46145	Congost	220
B12	4296	46109	Riera de Caldes	240
B16	4373	46044	Tenes	100
B17a	4315	46063	Caldes	240
B22	4211	46132	Ripoll	340
B24-R	4253	46165	Gallifa	560
B25	4327	46174	Tenes	250
B28	4308	46196	Tenes	570
B29	4422	46293	Avencó	1000
B30	4362	46293	Congost	530
B32-R	4397	46248	Avencó	340
B35-R	4403	46199	Vallcàrquera	380
B7a-R	4490	46161	Vilamajor	320
B7-R	4540	46102	Riera de les Arenes	320
LLOBREGAT BASIN				
SC1	3999	46458	Riera de Sant Cugat	760
L100	4039	46151	Cardener	165
L101	4049	46135	Llobregat	150
L102	4061	46179	Llobregat	180
L38	4007	46232	Cardener	220
L39	3974	46300	Cardener	250
L42	3931	46373	Cardener	386
L44-R	3942	46322	Negre	630
L45-R	4158	46166	Riera de les Nespres	540
L54	4009	46769	Llobregat	720
L56-R	4164	46796	Llobregat	1360
L57	4138	46770	Llobregat	840
L60a-R	4074	46601	Llobregat	487
L60c	4073	46550	Llobregat	460
L61-R	4167	46531	Merlès	550
L64a	4117	46283	Gavarresa	320
L67	4078	46395	Llobregat	320
L68	4071	46350	Llobregat	285
L77	3813	46049	Anoia	310
L82	3760	46121	Veciana	465
L90	4175	45848	Llobregat	20
L91	4137	45917	Llobregat	45
L94	4104	45953	Llobregat	60
L95	4068	46026	Llobregat	80
FOIX BASIN				
F24	3753	45865	Pontons	660
F25	3765	45861	Pontons	580

Site code	X_UTM	Y_UTM	Stream/River	Altitude (m.)
MIJARES BASIN				
MI1	6840	44770	Mijares	1370
MI10	6861	44561	Valbona	950
MI3	6839	44550	Mijares	920
MI4-R	6987	44445	Mijares	690
MI5	7212	44373	Mijares	310
MI6	7375	44302	Mijares	90
MI7	6900	44415	Albentosa	890
MI8-R	7173	44561	Villahermosa	760
MI9	7263	44380	Villahermosa	300
TURIA BASIN				
TU10	6849	43860	Turia	200
TU11-R	7046	43840	Turia	95
TU12-R	6720	43797	Sot	550
TU13	6535	44212	Turia	605
TU1-R	6943	44766	Alfambra	1470
TU2	6703	44958	Alfambra	1070
TU3	6635	44753	Alfambra	930
TU4-R	6627	44268	Arcos	900
TU6	6317	44737	Turia	1140
TU7	6545	44550	Turia	820
TU8	6489	44259	Turia	650
TU9-R	6717	43965	Turia	340
JÚCAR BASIN				
JU10	5805	43504	Júcar	670
JU11-R	6080	43332	Júcar	620
JU12	6338	43395	Júcar	515
JU13	6907	43489	Júcar	160
JU15	6679	43633	Magro	540
JU16	7081	43562	Magro	125
JU17	6093	44015	Guadazaón	830
JU19	6876	43573	Magro	290
JU1-R	6244	44543	Cabriel	1300
JU2-R	6141	44112	Cabriel	850
JU3	6434	43557	Cabriel	390
JU4	6644	43465	Cabriel	340
JU5	6684	43361	Cantaban	400
JU6	6048	44403	Guadazaón	1120
JU7-R	5987	44684	Júcar	1300
JU8-R	5985	44537	Júcar	1200
JU9	5651	44199	Júcar	840
SEGURA BASIN				
SE10-R	5972	41761	Corneros	650
SE13	6460	41635	Majada	60

Site code	X_UTM	Y_UTM	Stream/River	Altitude (m.)
SE15	6701	41023	Garruchal	100
SE16-R	5901	42151	Argos	780
SE18-R	5488	42302	Zumeta	720
SE1-R	5346	42246	Segura	1020
SE2-R	5345	42258	Madera	1020
SE3-R	5557	42219	Taibilla	950
SE4	5492	42565	Mundo	1040
SE5-R	5815	42675	Mundo	650
SE6	6175	42439	Mundo	330
SE7	5975	42104	Quipar	710
SE8-R	6314	42166	Perea	410
ALMANZORA BASIN				
AL1	5357	41323	Sauco	1000
AL10	5539	41327	Sierro	600
AL11	5533	41306	Sierro	760
AL14	5690	41280	Chercos	560
AL15	5666	41277	Chercos	760
AL17	5919	41342	Almanzora	180
AL2	5357	41323	Sauco	960
AL3	5403	41335	Herrerías	820
AL4	5427	41341	Almanzora	760
AL5	5493	41334	Bacares	690
AL6-R	5500	41310	Bacares	800
AL7-R	5493	41290	Bacares	920
AGUAS BASIN				
AG1-R	5826	41052	Aguas	260
AG2-R	5844	41055	Aguas	210
AG3	5862	41073	Aguas	180
AG5	5950	41115	Aguas	60
AG7-R	5883	41135	Jauto	210
ADRA BASIN				
AD1	5001	40701	Adra	80
AD2	4974	40862	Adra	370
AD3-R	4984	40762	Adra	200
AD4-R	4990	40935	Adra	680
AD5-R	4982	41038	Adra	1820
GUADALFEO BASIN				
GU10-R	4549	40786	Guadalfeo	160
GU11	4690	40943	Poqueira	1540
GU12	4677	40887	Poqueira	1000
GU13	4674	40851	Poqueira	500
GU14-R	4540	40938	Torrente	1100
GU15-R	4774	40967	Trevélez	1540
GU16	4674	40841	Guadalfeo	500

Site code	X_UTM	Y_UTM	Stream/River	Altitude (m.)
GU1-R	4636	40916	Chico	1860
GU2-R	4541	40989	Dúrcal	1300
GU3-R	4489	40949	Dúrcal	760
GU4	4487	40878	Dúrcal	500
GU5-R	4832	40931	Guadalfeo	1350
GU6-R	4814	40856	Guadalfeo	860
GU7-R	4733	40834	Guadalfeo	540
GU8	4657	40828	Guadalfeo	340
GU9	4596	40815	Guadalfeo	220
GUADALQUIVIR BASIN				
GE	2181	41586	Guadiamar	60

Chapter 7

DISTRIBUTION PATTERNS OF TRICHOPTERA ALONG IBERIAN MEDITERRANEAN COAST.

INTRODUCTION

Community ecology, and also biogeography, is interested in detecting patterns in communities and determining the factors implied (Townsend, 1989). Several forces have been identified as the responsible of these distribution patterns. Ecologists traditionally have focused in external (i.e., abiotic environment) and intrinsic (i.e., biotic interactions) processes (e.g., Power *et al.*, 1988), whereas biogeographers include historical factors (e.g., see Myers & Giller, 1988; Cornell & Lawton, 1992; Lobo, 1998; Bonada *et al.*, Chapter 3). However, the differentiation between ecological and historical processes is not always easy (Endler, 1982), because of the different scale of observation in space and time used when these factors are analyzed (Ball, 1975; Legendre, 1990). As consequence of these factors, organisms are distributed in patches in space and time rather than randomly or homogeneously, generating spatial and temporal heterogeneity (e.g., Pringle *et al.*, 1988).

Stream ecosystems are organized in a hierarchical framework at different scales of observation (Frissell *et al.*, 1986; Church, 1996). Distribution areas and patterns are strongly scale-dependent (Menge & Olson, 1990; Allen & Hoekstra, 1991; Poff, 1992; Holt, 1993; Levin, 1992) with different factors operate constraining the presence and abundance of taxa at each scale level (Poff, 1997). Several studies have been performed to identify and understand distribution of macroinvertebrate patterns in large (e.g., Corkum, 1989; Quinn & Hickey, 1990; Marchant *et al.*, 1995; Wright *et al.*, 1994; Kay *et al.*, 1999, 2001) and small geographical area Carter s (e.g., Ormerod & Edwards, 1987; Graça *et al.*, 1989) revealing the strong relationships between aquatic biota and environmental variables. Commonly, a large set of variables has been used to assess species autoecology and to understand distribution patterns. However, although factors determining distributions may be numerous and complex, are also intercorrelated (Prenda & Gallardo, 1992) and, in practice, few variables may allow us to define assemblages of species occurring in similar ecological conditions (e.g., Carter *et al.*, 1996; Wiberg-Larsen *et al.*, 2000). Multivariate analyses are very useful to demonstrate the hierarchical effect of variables in determining organism's distribution (Wiberg-Larsen *et al.*, 2000). The strong relationship between macroinvertebrates and environmental variables has been used all around to predict biological communities given a set of measured variables (e.g., Wright *et al.*, 1984; Smith *et al.*, 1989).

Mediterranean climate is characterized by a high seasonality with cold and wet winters and hot and dry summers (Köppen, 1923; Paskoff, 1973). The Mediterranean basin rivers subjected to these climatic patters have an annual and interannual variability in discharge regimes, with floods and droughts frequent and predictable (Gasith & Resh, 1999; Bonada *et al.*, Chapter 3). Mediterranean fauna is well known to have a high diversity, level of endemicity and complexity as the result of the interaction of complex historical and ecological factors, making the area unique from a biogeographical point of view (Balletto & Casale, 1989). In the Iberian Mediterranean area, numerous studies in taxonomy and ecology of macroinvertebrates have been done since the eighties (see Alba-Tercedor *et al.*, 1992), but although several taxonomical lists for specific macroinvertebrates cover all Iberian Peninsula, most of the ecological studies have been performed at a very small scale (e.g. one or few basins). Nowadays, studies at larger scales are increasing, and some of them are focused in looking at the environmental factors implied in the differential distribution of taxa (Mellado *et al.*, 2002; Vivas *et al.*, in press).

Trichoptera is a well-represented group in the Iberian Peninsula (with 331 species, Vieira-Lanero, 2000 with two new species from González & Ruiz, 2001 and Zamora-Muñoz *et al.*, 2002 —see Bonada *et al.*, Chapter 7) and highly endemic (González *et al.*, 1987). Although in this area Trichoptera has been studied since the middle of nineteen century, most of these studies have been focused in taxonomical rather than ecological aspects (but see for example, García de Jalón, 1986). Moreover, an unequal knowledge between caddisfly fauna in north and south areas of Iberian Peninsula is still noticed, with more studies performed around where specialists are (González *et al.*, 1987). Recent faunistic studies in southern areas of Spain noticed also a high endemicity (e.g., Ruiz *et al.*, 2001). Most of these studies are based on imago stages rather than larvae, although several larval keys have been published in the last 20 years (e.g., Viedma & García de Jalón, 1980; Millet, 1983; Camargo & García de Jalón, 1988; Zamora-Muñoz & Alba-Tercedor, 1992; Zamora-Muñoz *et al.*, 1995; 1997), including the recent work of Vieira-Lanero (2000). Likely, because of the poor and the high endemicity and diversity of species in the Iberian Peninsula (González *et al.*, 1987) and the incomplete knowledge of their larvae (Vieira-Lanero, 2000), few studies have been done focused on the autoecology of immature stages (but see Puig *et al.*, 1981; Gallardo-Mayenco *et al.*, 1998), although some ecological information can be found either, in taxonomical (e.g., Vieira-Lanero, 2000; Ruiz *et al.*, 2001) and macroinvertebrate community studies using species level (e.g., Legier & Talin, 1973; Puig *et al.*, 1981; Herranz & García de Jalón, 1984; Giudicelli *et al.*, 1985; Graça *et al.*, 1989; Gallardo-Mayenco, 1993). However, in Spain few studies have been performed in large-scale areas looking at their distribution and factors implied, contrasting with several examples that can be found in Europe (Leuven *et al.*, 1987; Czchorowski, 1994; Wiberg-Larsen *et al.*, 2000), North America (Ross, 1963) and South Africa (de Moor, 1992). The aims of this study are (1) to present the distribution of caddisflies in the mediterranean coast of Iberian Peninsula and (2) to elucidate the main ecological factors responsible of it.

METHODOLOGY

Sampling area

In this study, ten basins along the Mediterranean coast in east Spain were sampled (Figure 1): Besòs, Llobregat, Mijares, Turia, Júcar, Segura, Almanzora, Aguas, Adra and Guadalfeo (an extensive description of studied basins can be found in Robles *et al.*, in prep). The area is subjected to a mediterranean climate (Köppen, 1923), with a significant spring and autumn rainfall. Overall, along the coast, a thermal and pluviometric gradient is present (Robles *et al.*, in press), with annual precipitation going from less than 300 mm in the more arid basins in the southeast to over 800 mm in northern basins or in some other areas. Limestone and sedimentary materials are dominant, although some siliceous areas are also present as Sierra Nevada, Pyrenees and Montseny ranges (Figure 1). Sclerophyllous and evergreen trees and shrubs are dominant in basins, although in some areas deciduous and coniferous forests are present. However, vegetation has been altered since the beginning of human settlement (Grove & Rackman, 2001), and nowadays only some headwaters remain in a natural condition.

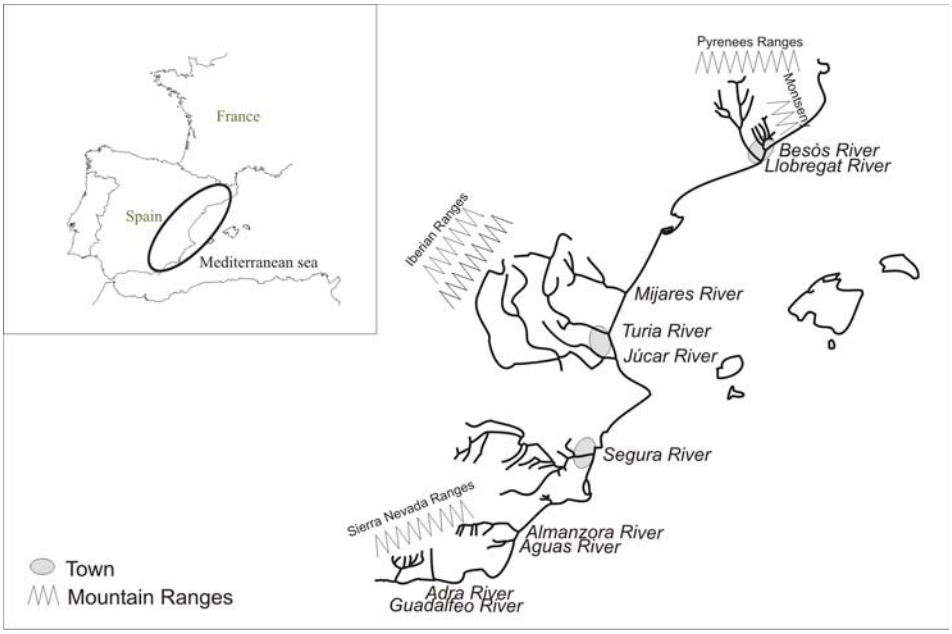


Figure 1. Basins sampled in the GUADALMED Project.

Because of the seasonality of the climatic patterns and the variability in landscape, topography and geomorphology, rivers in the sampled basins are highly variable in space and time. Overall, sampled rivers are subjected to high annual discharge variability, more or less important depending on the local conditions, with frequent floods and droughts (Molina *et al.*, 1994; Gasith & Resh, 1999). In space, a high variability of rivers have been sampled (Bonada *et al.*, in press a): alpine, siliceous and short rivers from Sierra Nevada, longer and calcareous rivers from Pyrenees and Iberian Ranges; small rivers and tributaries with a temporary condition, karstic streams and saline ramblas in the south-east.

As in other mediterranean regions, sampled basins have been largely affected by human activities (Trabaud, 1981) as agriculture, cattle, urbanization, salinization, water abstraction and regulation… (Conacher & Sala, 2001). All these factors have contributed to the river alteration in a direct or indirect way (Prat, 1993).

Sampling sites

A total of 157 sampling sites have been surveyed along Iberian Mediterranean coast four times in 1999 (spring, summer, autumn and winter) and three times in 2000 (spring, summer and autumn). They are part of the GUADALMED Project to assess the ecological status of the

Spanish mediterranean rivers according to the Water Framework Directive (European Parliament and Council, 2000). Sites are more or less equally distributed among all basins, and they include reference and non-reference sites (see Bonada *et al.*, in press b, for details in defining reference conditions). To study caddisfly distribution, only data from the first year was used. Several sampling sites and or seasons did not present Trichoptera larvae because the high pollution or because drought (mainly in summer). Thereby, data matrix was reduced to 372 samples (sites x seasons).

The variety of sampled river types and reaches implies the presence of different riparian communities with reaches without a structured riparian vegetation by natural conditions (i.e., ramblas and ephemeral rivers) to well preserved riparian forests in the headwaters of main rivers or tributaries (Suárez *et al.*, in press). However, the high human activity present in the sampled basins imply an extreme human alteration of riparian areas (Prat *et al.*, 1997, 1999) with numerous species introductions as *Platanus hispanica, Populus deltoides*, *Robinia pseudoacacia* and *Nicotiana sp.* Only in some reference and permanent headwaters, communities of *Salix alba*, *Corylus avellana*, *Populus nigra and Populus alba* are dominant. Sampling sites present a high variability in substrate types that enable the presence of abundant instream vegetation (e.g., mosses, diatoms, zygnematales and *Cladophora* sp.) and macrophytes (e.g., *Apium nodiflorum*, *Veronica* sp., *Rorippa* sp. and *Chara* sp.)

Sampling procedure

Sites were sampled following GUADALMED Protocol (Jáimez-Cuéllar, in press; Bonada *et al.*, Chapter 1) which is mainly designed as a bioassessment method, but the fine mesh size used (250 μm) and the absence of sampling restrictions in time, comparing with other procedures, allow us the use of samples for macroinvertebrate community studies (Bonada *et al.*, Chapter 6).

In each site, the index QBR for riparian quality (Munné *et al.*, 1998; in press; Suárez & Vidal-Abarca, 2000) and the IHF index for habitat diversity (Pardo *et al.*, in press) (see Annex 1 and 2 for the field sheets used in both indexes) were applied. Several physical and chemical parameters were measured *in situ* as pH, oxygen (mg/l and %), temperature, conductivity and discharge. Other water quality variables as ammonium, nitrites and phosphates were analyzed in the lab using the methods of GUADALMED Project (see Toro *et al.*, in press).

Macroinvertebrate samples were collected in riffles and pools with a kick-net of 250 μm mesh size. Samples were firstly examined in the field, and successive samples in both habitats are taken until no more families were found by the observer. Several invertebrates seen in the field but not taken in the sample were also recorded, as the large Heteroptera and Coleoptera. Samples were preserved in alcohol 70% and sorted in the lab. Caddisfly taxa were identified at the maximum level possible, and rank of abundances was recorded for each taxa: 1 from 1-3 individuals, 2 from 4-10, 3 from 11-100 and 4 for more than 100 individuals Because the large amount of undescribed larvae in the Iberian Peninsula (Vieira-Lanero, 2000) we were not able to identify all taxa at species level with certainty. When it was possible pupae and adults were collected in the field to ensure larvae identifications. Moreover, in some cases mature larvae were reared in the lab using a system inspired in Vieira-Lanero (1996).

Data analysis

Selecting biological data matrix

When macroinvertebrates are identified at the more precise taxonomical level possible, several difficulties are present when data matrices are used, because usually a mix of taxonomical level is found. Three situations may be responsible to that: (1) small individuals (first larvae stages) usually are difficult to identify at genus or species level, (2) as the knowledge of species of larvae is lower than the imagos, some species can be identified with more certainty than others, and (3) when it is impossible to achieve species level with larvae but some pupae have been collected and identified at species level. Consequently, different taxonomical levels are mixed between sites and even in a site, what may be a problem to achieve some objectives at community level (Cuffney *et al.*, 2002). To minimize this problem, the caddisfly data matrix with all individuals identified at maximum possible level (called 'caddis-max') was compared with the same matrix modified (called 'caddis-mod') according to the following assumptions:

> (1) If in one sample some individuals were identified with certainty at species level but small individuals were keeping at family (or genus), only species or genus data was used for that sample. However when all individuals from the sample were unable to be identified they were kept in family (or genus) level to avoid losses of information. That was a frequent case in Hydropsychidae and Rhyacophilidae.
>
> (2) If in one sample individuals were identified at genus but some pupae were collected and determined at species level, pupae were used at genus level jointly with the rest of individuals.

Both matrixes, caddis-max and caddis-mod, were compared using a Mantel test (Mantel, 1967) with the PCORD program (McCune & Mefford, 1999). This statistic method test differences between two similarity or distance matrices with the same objects (samples) to determine if distances among objects in one matrix (e.g., caddis-max) are or are not linearly correlated with the ones in the second matrix (e.g., caddis-mod). This test is equivalent to a non-parametric and multivariate test useful when biological data with many zeros is used. The result is a Mantel's standardized correlation coefficient (r_M) tested by random permutations (999 runs).

Spatial changes in caddisfly assemblages

Two ordination techniques of multivariate data were applied to analyze distribution patterns of caddisflies. Firstly, an indirect analysis of Correspondence Analysis (CA) using biological data was performed. This ordination technique allows us to relate objects (samples) and descriptors (taxa) in a low-dimensional space. The measure used is the χ^2, appropriated for semiquantitative data. It has been considered to produce better results than Principal Coordinate Analysis (PCA) with biological data, because matrices usually have numerous null values and χ^2 distance exclude double-zeros (Legendre & Legendre, 1998). Eigenvalues results (an indication of the percentage of variability explained by each canonical axis) were kept and compared with the ones obtained using a partial Canonical Correspondence Analysis (pCCA) to understand the proportion of caddisfly distribution explained by measured environmental variables. Partial CCA analysis is a direct ordination method similar to partial Redundancy Analysis (pRDA) but using χ^2 rather than Euclidean distances. This method obtains samples ordination according to the environmental constrains provided by an environmental variables matrix, and extracting the influence of some covariates on the biological data. A pCCA analysis was performed in front of a simple CCA to extract the influence of seasonality in sampling samples, because it presented a significant effect after a MRPP test (Multi-response Permutation Procedures) comparing four sampled seasons (A=0.003, p-value=0.022). Seasonality was included as four dummy covariables (spring, summer, autumn and winter). Rare species were down weighted to avoid bias in the final results in CA and pCCA analysis.

Environmental data matrix was built up using the variables measured in GUADALMED Project (Table 1). Physical and chemical parameters included are those measured in the field or obtained in the lab. Oxygen was removed from the analysis because the incomplete data set. Biological indicators of the composition and diversity of the macroinvertebrate community were also used, as IBMWP (Alba-Tercedor y Sánchez-Ortega, 1988; Alba-Tercedor, 1996; Alba-Tercedor & Pujante, 2000), and the IASPT (the ratio between IBMWP and number of taxa).

Geomorphological variables as the basin geology, altitude, stream order and so on were also measured for each site and included in the analysis (variables from group C in Table 1). Finally, complete data obtained from QBR and IHF in each site (variables from group D and E in Table 1 —see Annex 1 and 2 for field sheets) were included. A variable measuring temporality was added to the analysis (group A variable in Table 1) to check its influence on the caddisfly distribution. Variables were tested for autocorrelation using the non-parametric Spearman correlation coefficient. Variables highly correlated with the others were deleted from the analysis. Because most of the variables had a non-normal distribution (after a Shapiro-Wilk's test) and some of them were highly skewed (e.g., conductivity, nitrites, ammonium) they were log-transformed previously to the multivariate analysis. Canonical axes obtained with the pCCA ordination and environmental variables (selected by forward selection method) were tested for significance using a Monte Carlo permutation test (199 runs). The CANOCO Program was used to compute all ordination techniques (ter Braak & Smilauer, 1998).

To elucidate the meaning of canonical axis and understand the factors explaining caddisfly distributions, r-Pearson correlations were calculated between canonical axis and environmental variables. Several groups of samples with different caddisfly assemblages explained by different environmental variables were differentiated in the pCCA plots. To corroborate these groups from a statistical point of view, samples were clustered using its projections into canonical axis with a k-means method. This method divides samples in k-groups predefined using the number of the different caddisfly associations seen in the pCCA results. The analysis looks for groups of samples maximizing the differences among groups of samples and minimizing differences among samples from the same group (Legendre & Legendre, 1998). Finally, a discriminant analysis step-by-step using the Wilks' Lambda method with SPSS (SPSS, 1999) was used to select the environmental variables more significant in defining each group of caddisfly associations. The Wilks' Lambda statistic is calculated for each variable and has values between 0 and 1, with values near 0 indicating that groups present differences for that variable. Consequently, the method step-by-step identifies in hierarchical way variables with a minimum value of Wilks' Lambda. After that, the final selection of discriminant variables is done using the F statistic and a fixed p-value associated at 0.05 to enter a variable and 0.10 to remove it as default (Ferrán-Aranaz, 2001).

Table 1. Variables measured and used in the analysis. A=variable assessing temporality; B=physical, chemical and biological variables; C=geomorphological variables; D&E=structural variables. D corresponds to the values from each section from the index of habitat diversity (IHF) proposed by Pardo *et al.* (in prep). E corresponds to the values of each section from the index of riparian vegetation quality (QBR) proposed by Munné *et al.* (1998). The field sheet of both indexes is in Annex 1 and 2.

	Variable	**Code**	**Considerations**
A	Temporality	Tempo	Number of seasons that the rivers was dried: (0) permanent, (1) 1 season, (2) 2 seasons, (3) 3 seasons
B	NH_4^+	NH4+	Concentration in mg/l of NH4+
	$N\text{-}NO_2^-$	NO2-	Concentration in mg/l of N-NO2-
	$P\text{-}PO_4^{3-}$	PO43-	Concentration in mg/l of P-PO43-
	Discharge	Discharge	Water discharge in l/s
	pH	pH	Water pH
	Temperature	Tempe	Water temperature in °C
	Conductivity	Conductivity	Water conductivity at 25°C in mS/cm
	IBMWP	IBWMP	Biological index for water quality (Alba-Tercedor & Sánchez-Ortega, 1988)
	IASPT	IASPT	Relationship between IBMWP and number of families
C	%sil-b	%Sil	Percentage of siliceous materials in basin from each site
	%cal-b	%Cal	Percentage of calcareous materials in basin from each site
	%sed-b	%Sed	Percentage of sedimentary materials in basin from each site
	Basin Area	Basin-Area	Basin area drained in each site
	Altitude	Altitude	Altitude from each site in m.a.s.l.
	Stream Order	Str-Ordre	Stream order at 1:250000
	Channel Width	Chan-Width	Channel Width: until 1m (1), from 1 to 10m (2), over than 10m (3)
	Channel Shape	Chan-Shape	Channel Shape according to the QBR field sheet
D	Embeddedness	Embed	The extent of embeddedness of the stream bed
	Riffles vs. Pools	R/L	It is measure according to the riffles frequencies in sampling reach
	Substrate composition	Substrat	Types and abundance of substrates present in sampling reach
	Flow and Depth regimes	Flow-Depth	Types of regimes in sampling reach
	Shade	Shade	% of shade over the sampling reach
	Heterogeneity elements	Hetero	Number and abundance of heterogeneity elements as leaf litter, branches, logs...
	Instream Vegetation	Inst-Veg	Types and abundance of different instream vegetation formations
E	Riparian cover	Rip-Cove	Proportion of the riparian are cover by trees and shrubs
	Riparian structure	Rip-Stru	Proportion of riparian vegetation composed by trees and shrubs separately
	Riparian Quality	Rip-Qual	Absence of introduced species, and other human impacts in riparian vegetation
	Channel Quality	Chan-Qua	Absence of human impacts altering channel form.

Once groups of samples and caddisflies and the significant environmental variables associated were established, significant differences between groups of samples in caddisfly assemblage were checked using a MRPP analysis with 999 runs. Further, an IndVal (Indicator Value) method (Dufrêne & Legendre, 1997) was applied to get the caddisfly assemblage more representatives in each group of samples. This procedure, examine characteristic taxa from a predefined group of objects (from the k-means) according to the presence and abundance of each taxa in each group independently of the others. Each taxon has associated an indicator value (IV-value) and a p-value obtained by Monte Carlo permutations (9999 runs). PCORD Program (McCune & Mefford, 1999) was used to carry out this analysis.

Seasonal changes in caddisfly assemblages

To check the effect of seasonality and study changes in caddisfly community along year, a CCA analysis was performed for all samples using seasons as dummy variables. Rare species were down weighted. Canonical axes were tested for significance using a Monte Carlo test with 199 runs.

Variance partition of spatial and temporal patterns

To determine the proportion of all caddisfly variability explained by measured variables and seasonality and their interaction, a Variance Partition was performed (Bocard *et al.*, 1992). To carry out this analysis, two CCA and two pCCA were performed: (1) with environmental variables, (2) with seasonality variables, (3) with environmental variables and seasonality covariables and (4) with seasonality variables and environmental covariables. (3) and (4) steps (pCCA) allow us to separate what is purely environment or seasonality and what is a result of the interaction. The sum of canonical eigenvalues of each analysis respect the sum of all eigenvalues (i.e., inertia) gives the percentage of variation explained by each group of variables. Non-explained variability was also calculated. Moreover, the percentage explained by environmental variables was partitioned to detect the proportion attributed to geomorphologic, temporality, physical-chemical and biological parameters. To perform that, successive CCA analysis using each subgroup of variables were done, and sum of all canonical eigenvalues were kept to calculate percentages.

RESULTS

Taxa distribution

A high and significant correlation was obtained comparing caddis-max with caddis-mod matrix (r_M=0.9822 and p-value=0.0101) indicating that similar information is provided using both matrixes. We decided to use the caddis-mod matrix to simplify the analysis and the interpretation of final results. A total of 71 taxa (including species and genus) were obtained (Annex 3). Taxonomical notes of these taxa are found in Bonada *et al.* (Chapter 6). Number of taxa is variable between basins (Figure 2). Segura basin presents the highest value of taxa whereas in Aguas and Mijares less than 20 taxa have been found. The rest of basins present intermediate values between 20 and 35 taxa. Some of collected taxa are ubiquitous whereas other are exclusive from one o more basins.

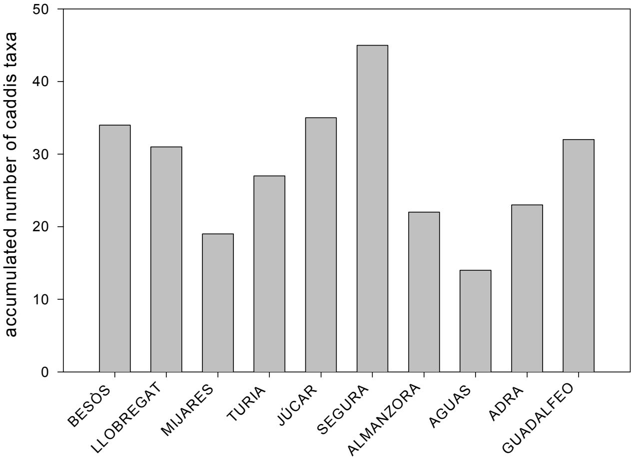


Figure 2. Number of accumulated taxa found in each sampling basin. Basins are ordered from north to south.

Table 2 represents the maximum of abundances of the most common caddisfly taxa (more than 1% of its presence in all samples) for each basin. Only *Hydropsyche* gr. *pellucidula* and *Hydroptila* sp. (Table 2) have been found in all sampled basins. Many caddisflies lack in only one basin, as *Agapetus* sp., *C. marginata*, *M. aspersus*, *H. exocellata*, *Polycentropus* sp., *Tinodes* sp.). In general, several taxa are absent in northern basins whereas other do in the southern ones. For instance, *Athripsodes* sp., *Rh. nevada*, *S. argentipunctellus*, *H. infernalis*, *M. moestum*, have been widely collected in most of southern basins (Segura, Almanzora, Aguas, Adra and Guadalfeo). Instead, *Limnephilus* sp. (mainly from *guadarramicus* species), *H. sp1*, *Rh. dorsalis*, *Chaetopteryx* sp., *H. radiatus*, *H. siltalai*, *M. azurea* and *P. cingulatus* are more distributed in northern basins (Besòs, Llobregat, Mijares, Turia and Júcar). Segura basin, often displays a mixture of taxa widely distributed in northern and southern basins, as *H. siltalai, H. sp1, Chaetopteryx* sp., *Rh. nevada*, *H. infernalis* and *M. moestum*. Some affinities can be observed between Besòs/Llobregat and Adra/Guadalfeo (the most northern and southern basins respectively) with *P. latipennis*, and the more widely distributed *P. montanus*. On the other hand, *O. albicorne* and *Rh.* gr. *tristis* have been collected only in Besòs and Llobregat basins, whereas *A. chauviniana* and *Rh.* cf. *occidentalis* were found in Adra and Guadalfeo basins. Some exclusive families have been collected in the large rivers Turia, Júcar and Segura, as *Ithytrichia* sp., *C. lepida*, *Ceraclea* sp., *O. angustella* and *H. brevis*.

Table 2. Maximum abundance recorded in each basin for each caddisfly species. Taxa are ranked according its exclusivity from northern to southern basins. Each sample is represented by one or two letters from the basin: B=Besòs, L=Llobregat, M=Mijares, T=Turia, J=Júcar, S=Segura, AL=Almanzora, AG=Aguas, AD=Adra, G=Guadalfeo.

	B	L	M	T	J	SE	AL	AG	AD	G
Odontocerum albicorne	2	1	0	0	0	0	0	0	0	0
Rhyacophila gr. *tristis*	1	1	0	0	0	0	0	0	0	0
Halesus radiatus	2	1	2	2	3	0	0	0	0	0
Wormaldia sp.	3	0	0	1	1	0	0	0	0	0
Rhyacophila dorsalis	1	3	2	2	1	0	0	0	0	0
Potamophylax cingulatus	2	3	0	0	2	0	0	0	0	0
Mystacides azurea	2	2	2	1	1	2	0	0	0	0
Chaetopteryx sp.	1	1	0	2	1	1	0	0	0	0
Tinodes waeneri	1	0	0	0	0	1	0	0	0	0
Hydropsyche siltalai	4	4	0	0	2	1	0	0	0	0
Stenophylax sp.	1	0	0	0	1	3	1	0	0	0
Limnephilus sp.	4	2	3	2	3	0	0	1	0	0
Hydropsyche sp1	0	1	1	0	3	3	0	0	0	0
Hydropsyche bulbifera	0	0	2	0	0	3	0	0	0	0
Hydropsyche brevis	0	0	1	2	3	3	0	0	0	0
Ithytrichia sp.	0	0	0	2	2	1	0	0	0	0
Ceraclea sp.	0	0	0	0	1	1	0	0	0	0
Cheumatopsyche lepida	0	0	0	0	3	2	0	0	0	0
Drusus bolivari	0	0	0	0	0	2	0	0	0	0
Metalype fragilis	0	0	0	0	0	1	0	0	0	0
Allogamus sp.	0	1	0	1	0	3	3	0	0	0
Halesus tesselatus	2	0	0	1	0	1	0	0	3	2
Rhyacophila meridionalis	2	3	0	0	0	2	2	0	2	0
Agapetus sp.	3	0	1	1	3	3	1	3	3	3
Potamophylax latipennis	1	3	0	0	0	0	0	0	3	2
Polycentropus sp.	3	3	0	2	2	3	3	2	2	2
Sericostoma sp.	2	3	0	1	2	3	0	0	1	2
Plectrocnemia sp.	1	2	0	0	1	2	0	0	1	1
Philopotamus montanus	3	1	0	0	0	1	0	0	1	2
Hydropsyche instabilis	3	2	3	3	0	3	3	0	3	3
Hydropsyche exocellata	4	4	3	3	4	2	3	0	3	1
Mesophylax aspersus	3	3	2	3	1	3	2	0	1	2
Tinodes sp.	1	1	1	1	1	1	2	1	0	2
Hydropsyche gr. *pellucidula*	3	3	3	3	3	3	2	3	3	3
Hydroptila sp.	3	4	2	3	4	3	3	3	2	2
Chimarra marginata	0	4	3	1	4	1	1	3	2	2
Rhyacophila munda	0	0	2	1	1	3	2	2	2	3
Setodes argentipunctellus	0	0	0	1	2	3	3	3	2	1
Lasiocephala basalis	0	0	0	1	3	2	0	0	1	3
Orthotrichia angustella	0	0	0	0	3	0	0	0	0	0
Oxyethira sp.	0	0	0	0	0	2	2	3	0	0
Micrasema moestum	0	0	0	0	0	3	4	0	0	1
Hydropsyche infernalis	0	0	0	0	0	3	1	1	2	2
Rhyacophila nevada	0	0	0	0	0	3	3	0	1	2
Athripsodes sp.	0	0	0	0	0	0	3	1	1	2
Anomalopterygella chauviniana	0	0	0	0	0	0	0	0	1	2
Rhyacophila cf. *occidentalis*	0	0	0	0	0	0	0	0	1	2
Micrasema longulum	0	0	0	0	0	0	0	0	0	2

Spatial patterns of distribution

Environmental variables were weakly correlated when rho-Spearman coefficient between pair of variables were obtained (not shown), and thereby none of them were excluded from the analysis.

Results from the pCCA analysis are in Table 3. Canonical axes from CA and pCCA analysis represent a low percentage of caddisfly variability in samples, with 7.4% in the first CA-axis and 5.8% in the first pCCA-axis. However, the results indicate that a high percentage of all caddisfly variability showed in the first CA-axis is explained by environmental variables (78.3% for the first axis, 42.3% for the second, 33.8% for the third and 31.6% for the fourth). This indicates that the measured variables are among the responsible to explain major differences in caddisfly distribution. Moreover, Monte Carlo permutation tests indicate that all canonical axes are significant with the set of variables used. Some variables (i.e., nitrites, discharge, temperature, channel shape, riparian quality, phosphates and riparian cover) were not significant (after applying the forward selection method in CANOCO Program) and consequently they were not used in the analysis. The pCCA graphs for samples and caddisflies and environmental variables are shown in Figure 3 (first and second axes) and 4 (second and third axes). Only the three first canonical axes were used because they include the maximum variability expressed by the environmental variables. First axis appears negatively correlated with altitude, siliceous basin, biological indexes and high values of all riparian and habitat features (Table 4), differentiating samples with good ecological quality located in

Table 3. Eigenvalues and % of explained variation obtained from CA and CCA analysis. Results from Monte Carlo test checking for axis significance in CCA are presented on the bottom.

Correspondence Analysis (CA)				
	X_1	X_2	X_3	X_4
Eigenvalues	0.733	0.646	0.549	0.484
Cumulative % variance	7.4	13.9	19.4	24.3

Canonical Correspondence Analysis (PCCA)				
	X_1	X_2	X_3	X_4
Eigenvalues	0.574	0.276	0.186	0.153
Cumulative % variance	5.8	8.7	10.6	12.1

Monte Carlo test (199 permutations)		
	F	p-value
Significance of first canonical axis	21.469	0.005
Significance of all canonical axis	3.715	0.005

headwaters at high altitude from lowland reaches. Second axis is positively related to chemical variables, discharge, basin area, channel width and others, whereas it is negatively associated with high values of riparian and biological quality, several habitat characteristics and temporality (Table 4). Finally, the third axis is associated to temperature, stream order and sedimentary geology in a positive direction and to riparian and habitat characteristics in the negative one (Table 4). According to Figure 3, a gradient of caddisfly species appear from left to right side of the graph and three groups may be differentiated. Headwaters and high altitude samples with a high substrate diversity, located in the left, are associated with *Glossosoma* sp., *A. chauviniana*, *M. longulum*, *H. tesselatus*, *Rh.* cf. *occidentalis* and *H. tibialis* whereas lowland rivers in the right present *H. exocellata*, *P. pusilla*, *P.* cf. *ctenophora* and *H. brevis*. In the middle, a group of midstream samples associated with several Hydropsychids, Philopotamids, Polycentropodids and Psychomiids are present. Second axis in Figure 3 appears to differentiate between small temporary streams from middle and large streams. Few taxa is associated to positive values of second axes, as *Rh. fasciata, Rh. dorsalis, Ecnomus* sp. and several Hydropsychids, characteristic from middle reaches.

Figure 3. pCCA plots representing first (X_1) and second (X_2) axis. The graph on the top shows the distribution of samples, and the one on the bottom the distribution of taxa. Adjacent graph display the position of environmental variables. Each sample is represented by one or two letters from the basin: B=Besòs, L=Llobregat, M=Mijares, T=Turia, J=Júcar, S=Segura, AL=Almanzora, AG=Aguas, AD=Adra, G=Guadalfeo.

Table 4. Pearson correlations (r) between environmental variables and the three canonical axis from CCA. **p-value<0.01, *p-value<0.05. For codes explanation see Table 1.

	X_1-CCA		X_2-CCA		X_3-CCA	
Temporality	-0.017		-0.268	**	-0.017	
NH_4^+	0.322	**	0.386	**	-0.080	
NO_2^-	0.112	*	0.111	*	0.006	
PO_4^{3-}	0.223	**	0.229	**	0.02	
Discharge	0.191	**	0.337	**	0.040	
pH	-0.042		0.106	*	0.025	
Temperature	0.230	**	-0.072		0.275	**
Conductivity	0.641	**	-0.035		0.062	
IBWMP	-0.490	**	-0.478	**	-0.013	
IASPT	-0.596	**	-0.193	**	-0.108	
%Sil	-0.382	**	-0.057		0.074	
%Cal	0.454	**	0.185	**	-0.038	
%Sed	0.395	**	-0.018		0.326	**
Basin-Area	0.597	**	0.370	**	0.022	
Altitude	-0.561	**	-0.114	*	0.055	
Stream Order	0.366	**	0.227	**	0.302	**
Channel Width	0.176	**	0.438	**	0.019	
Channel Shape	-0.371	**	-0.088		0.048	
Embed	-0.109	*	0.057		-0.237	**
R/L	-0.165	**	0.240	**	-0.235	**
Substrat	-0.112	*	0.211	**	0.146	**
Flow-Depth	-0.227	**	0.113	*	-0.192	**
Shade	-0.390	**	-0.182	**	-0.151	**
Hetero	-0.416	**	-0.157	**	-0.098	
Inst-Veg	-0.089		0.125	*	-0.208	**
Rip-Cove	-0.404	**	-0.287	**	-0.01	
Rip-Stru	-0.322	**	-0.299	**	-0.073	
Rip-Qual	-0.271	*	-0.148	**	-0.135	**
Chan-Qual	-0.403	**	-0.203	**	-0.001	

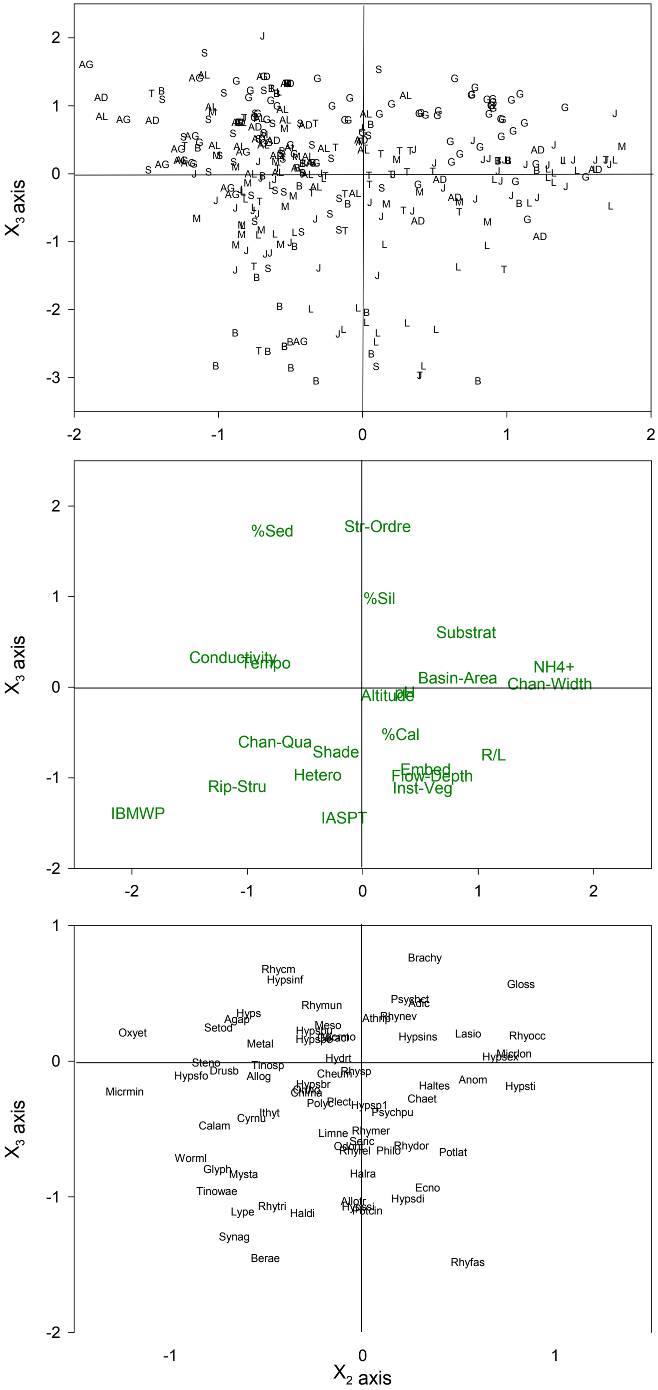


Figure 4. pCCA plots representing first (X_1) and third (X_3) axis. The graph on the top shows the distribution of samples, and the one on the bottom the distribution of taxa. Adjacent graphs display the position of environmental variables. Each sample is represented by one or two letters from the basin: B=Besòs, L=Llobregat,, M=Mijares, T=Turia, J=Júcar, S=Segura, AL=Almanzora, AG=Aguas, AD=Adra, G=Guadalfeo.

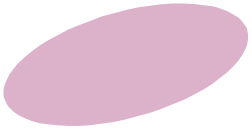
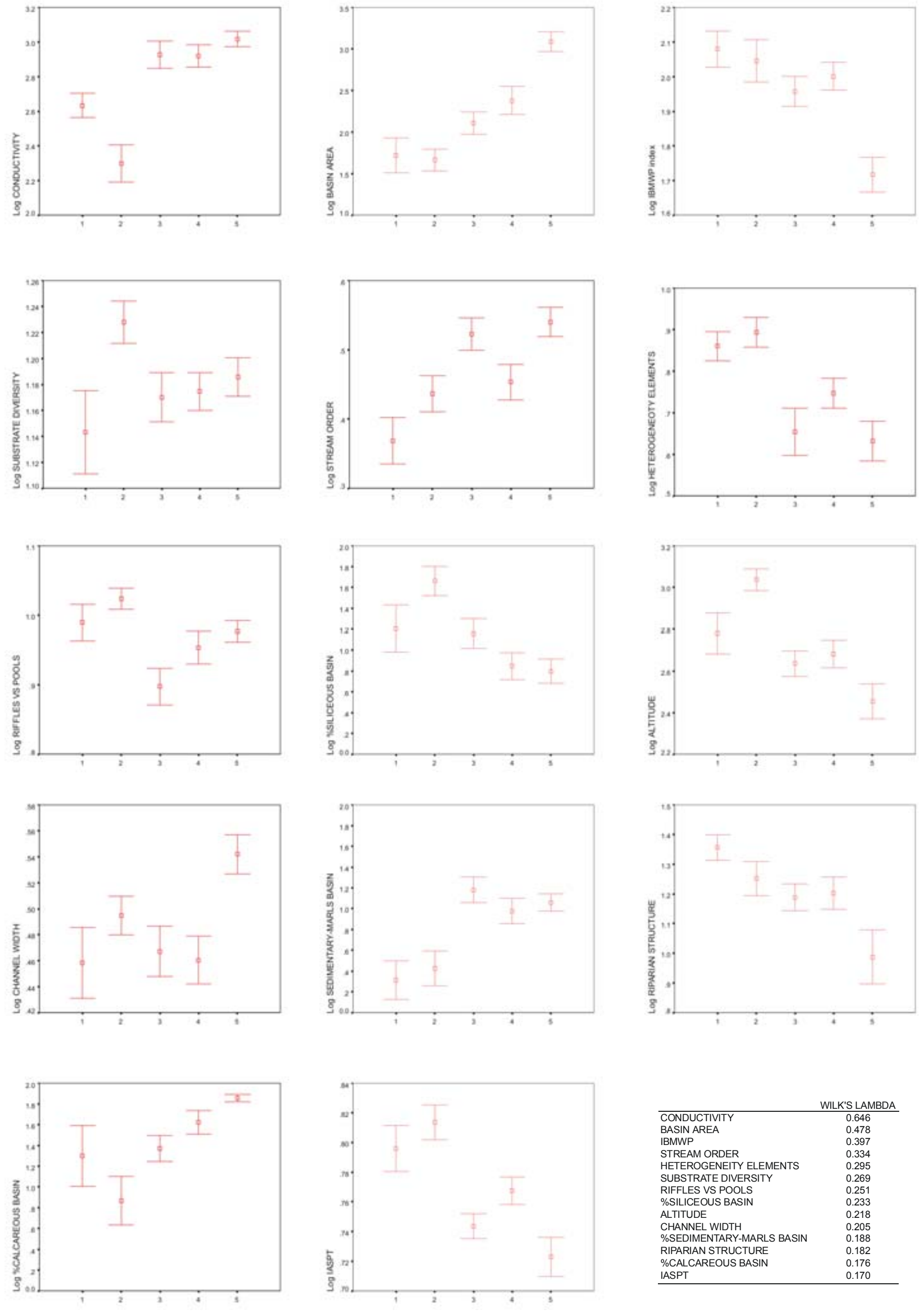


Figure 5. pCCA plots representing sites on first (X_1) and second (X_2) axis on the top, and first (X_1) and third (X_3) on the bottom. Samples are labeled according to the results from the K-means analysis. Circles represent the extension of each group.

On the other hand, more taxa is associated to the small rivers located on the negative part of second axis, as *M. minimum, Oxyethira* sp., *Wormaldia* sp., *Stenophylax* sp., *G. pellucidus, Agapetus* sp., *S. argentipunctellus,...* and the ones highly related to a well- developed riparian forest, *Beraea* sp., *Allogamus* sp., *Synagapetus* sp., *D. bolivari* or *H. digitatus*. In Figure 4 where second and third axes are plotted, samples from second axis are segregated more clearly than in Figure 3. Some temporary and sedimentary-marl samples with high natural conductivity and high stream order from the most arid basins of Aguas, Almanzora and Segura (Figure 4) are distinguished in the top-left part of the axis, with *H. infernalis*, *H. bulbifera*, *Agapetus* sp., *M. aspersus, Oxyethira* sp., *Rh.* cf. *munda* and *S. argentipunctellus*. Through the lower part of the axis, samples associated to middle reaches of rivers (in the central part of the graph) are associated with species as *Ithytrichia* sp., *Cyrnus* sp., *Polycentropus* sp., *C. marginata*, whereas more pristine headwaters (in the lower part of the graph) are characterized by *Wormaldia* sp., *G. pellucidus, M. azurea, Tinodes waeneri, Halesus* sp., *Lype* sp., *Rh.* gr. *tristis* and others. Consequently, from Figures 3 and 4, five groups of sites may be distinguished: headwater sites with high altitude, diverse habitat characteristics and siliceous basins (top-left from Figure 3); headwater samples at medium altitudes with high riparian structure and biological quality (bottom area of Figure 4); low altitude and temporary sedimentary samples with high conductivity (top-right in Figure 4); low altitude samples located in lowland reaches from medium to large rivers with a poor biological and chemical quality (top-right from Figure 3); and middle parts of river sites located at medium altitudes (central area of second axis from Figure 4). To verify the presence and identity of each group and to classify properly all samples, a k-means cluster using 5 pre-defined groups was applied to all samples. Figure 5 display de results of this analysis. Final k-means groups are those that we should expect according to the interpretations of samples in Figure 3 and 4. Group 4 is the biggest group with 102 objects, followed by group 3 with 97. On the other hand, smallest groups (k-means-1 with 39 samples and k-means-2 with 54) have samples highly dispersed indicating that more diverse and less abundant caddisfly are present.

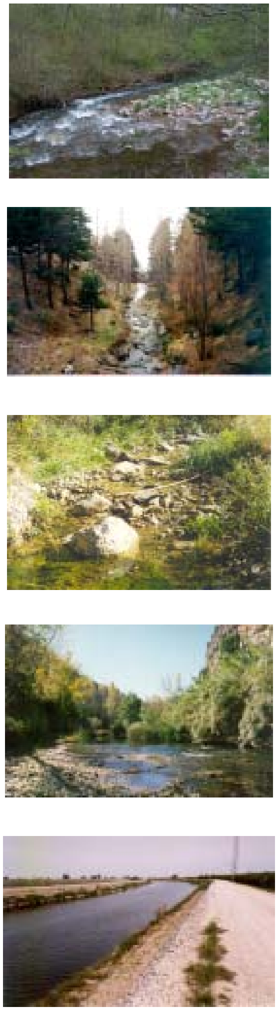
Discriminant analysis selected 14 variables that differentiate k-means groups (Figure 6). Seven variables are geomorphological features (basin area, stream order, altitude, channel width, %siliceous, calcareous and sedimentary-marl basin) whereas the rest are habitat, riparian, habitat and biological properties. Conductivity is the only physical-chemical variable that discriminates groups of samples, being higher in groups 3, 4 and 5. According to Figure 6, group 1 and 2 correspond to headwaters samples differing in altitude, basin geology, channel width, stream order and substrate diversity. Two groups of samples appear located in middle



	WILK'S LAMBDA
CONDUCTIVITY	0.646
BASIN AREA	0.478
IBMWP	0.397
STREAM ORDER	0.334
HETEROGENEITY ELEMENTS	0.295
SUBSTRATE DIVERSITY	0.269
RIFFLES VS POOLS	0.251
%SILICEOUS BASIN	0.233
ALTITUDE	0.218
CHANNEL WIDTH	0.205
%SEDIMENTARY-MARLS BASIN	0.188
RIPARIAN STRUCTURE	0.182
%CALCAREOUS BASIN	0.176
IASPT	0.170

Figure 6. Results from the Discriminant Analysis, with the most significant variables between k-groups. Mean and confidence intervals at 95% are presented. Plots are ordered from top-left to bottom-right according to their weight in discriminant analysis.

reaches of rivers (k-means 3 and 4), characterized by intermediate altitude and channel width and lower riparian structure. Conductivity is also similar between both midstream groups although the higher percentage of sedimentary basins mainly composed by marls in group 3 and the dominance of pools with a lower IASPT, suggest us to consider it as a group of samples with rambla type features. In contrast, group 4 would correspond to common



GROUP 1: CALCAREOUS/SILICEOUS HEADWATERS
Calcareous and siliceous basin with a small area. Medium altitude. Low stream order and narrow channel. High biological quality and riparian structure. Riffles dominant with low substrate diversity and high heterogeneity elements. Water with low conductivity.

GROUP 2: SILICEOUS HEADWATERS
Mainly siliceous basins with small area. High altitude. Medium stream order and narrow channel. High biological quality and riparian structure. Riffles dominant with high substrate diversity and heterogeneity elements. Water with very low conductivity.

GROUP 3: SEDIMENTARY-MARLS MIDSTREAMS
Mainly sedimentary-marls basin with medium basin area. Medium-low altitude. High stream order and narrow channel. High biological quality and medium riparian structure. Low IASPT. Pools dominant with medium substrate diversity and scarce heterogeneity elements. Water with high natural conductivity.

GROUP 4: CALCAREOUS/SEDIMENTARY MIDSTREAMS
Calcareous and sedimentary basin with large basin area. Medium-low altitude. Medium stream order and narrow channel. High biological quality and medium riparian structure. Medium IASPT. Riffles and pools dominant with medium substrate diversity and heterogeneity elements. Water with high conductivity.

GROUP 5: CALCAREOUS/SEDIMENTARY LOWLAND REACHES
Calcareous and sedimentary basins with very large basin area. Low altitude. High stream order and wide channel. Low biological quality and riparian structure. Riffles and pools dominant with medium substrate diversity and scarce heterogeneity elements. Water with high conductivity.

Figure 7. Groups significance according to the results obtained from discriminant analysis.

midstreams with a mix of calcareous and sedimentary geology and riffles as a dominant macrohabitat. Finally, k-means-5 includes lowland reaches with calcareous and sedimentary basins and poor ecological quality. Thereby, according to our analysis, caddisfly assemblages along Mediterranean coast are segregated in five groups of samples differing in environmental conditions (see Figure 7). These groups can be defined as: (1) Calcareous/Siliceous headwaters, (2) Siliceous headwaters, (3) Sedimentary-marl midstreams, (4) Calcareous/sedimentary midstreams and (5) Calcareous/Sedimentary lowland reaches. In Table 5 the number of samples from each group separated by basins is presented.

Table 5. Number of samples in k-means groups detailed by sampling basins. Basins are ordered from north to south.

	GROUP 1	**GROUP 2**	**GROUP 3**	**GROUP 4**	**GROUP 5**
BESÒS	16	1	7	8	8
LLOBREGAT	10	0	2	11	31
MIJARES	2	2	5	12	6
TURIA	5	3	8	16	5
JÚCAR	5	1	3	22	28
SEGURA	2	3	17	16	0
ALMANZORA	0	5	12	8	0
AGUAS	1	0	11	3	0
ADRA	0	4	11	2	2
GUADALFEO	0	35	21	2	0
TOTAL	41	54	97	100	80

Interesting to notice that northern basins have most of the calcareous/siliceous headwaters (group 1) whereas siliceous headwaters are dominant in southern basins. Similarly, most of the medium and large rivers with lowlands that allow the presence of caddisfly are present only from Júcar through the north. Midstream reaches also appear quite segregated between northern and southern areas. Sedimentary-marl midstreams are dominant in Segura, Almanzora, Aguas, Adra and Guadalfeo, whereas northern basins have midstreams with influences by a more calcareous basin.

Differences between k-means groups in caddisfly community are highly significant according to MRPP results (A=0.2176, p-value=0.000). These differences are observed when IndVal results are analyzed (Table 6). Because of the low abundance and frequency of many caddisflies, few taxa have high indicator values (IV-value>25) although many are

Table 6. IndVal results for each group of sites separately. Indicator values (IV-value) and significance for significant taxa in each group are presented. Taxa is ordered according to their p-value.

CALCAREOUS/SILICEOUS HEADWATERS		
GROUP 1	IV-value	p-value
Sericostoma sp.	44.1	0.001
Hydropsyche siltalai	35.4	0.001
Limnephilus (guadarramicus) sp.	22.1	0.001
Halesus radiatus	22	0.001
Rhyacophila dorsalis	20	0.001
Potamophylax latipennis	18.6	0.001
Potamophylax cingulatus	17.9	0.001
Hydropsyche dinarica	12.2	0.001
Chaetopteryx sp.	12	0.001
Wormaldia sp.	10.3	0.001
Polycentropus sp.	24.7	0.002
Philopotamus montanus	11.6	0.002
Synagapetus sp.	7.7	0.002
Rhyacophila relicta	5.1	0.01
Mystacides azurea	8.5	0.017
Halesus digitatus	4.9	0.019
Plectrocnemia sp.	10	0.02
Rhyacophila meridionalis	6.5	0.021
Glyphotaelius pellucidus	4.6	0.025
Rhyacophyla gr. *tristis*	6.7	0.033

SILICEOUS HEADWATERS		
GROUP 2	IV-value	p-value
Hydropsyche instabilis	88.2	0.001
Lasiocephala basalis	58.8	0.001
Rhyacophila nevada	47.9	0.001
Athripsodes sp.	39.6	0.001
Micrasema moestum	21.7	0.001
Halesus tessellatus	21.4	0.001
Rhyacophila cf. *occidentalis*	14.8	0.001
Anomalopterygella chauviniana	11.1	0.001
Migrasema longulum	11.1	0.001
Philopotamus montanus	9.3	0.001
Potamophylax latipennis	10.5	0.005
Sericostoma sp.	14.6	0.008
Glossosoma sp.	3.7	0.014
Brachycentrus (O.) maculatum	3.7	0.028
Rhyacophila meridionalis	5.3	0.041

SEDIMENTARY-MARLS MIDSTREAMS		
GROUP 3	IV-value	p-value
Hydropsyche gr pellucidula	48.4	0.001
Agapetus sp.	24	0.001
Mesophylax aspersus	23.5	0.001
Rhyacophila munda	21	0.001
Hydropsyche sp.	12.8	0.001
Hydropsyche infernalis	11.5	0.001
Setodes argentipunctellus	11.4	0.001
Stenophylax sp.	4	0.0611
Rhyacophila cf. *munda*	2.1	0.0611

CALCAREOUS/SEDIMENTARY MIDSTREAMS		
GROUP 4	IV-value	p-value
Hydroptila sp.	41.9	0.001
Hydropsyche gr. *pellucidula*	27.1	0.001
Chimarra marginata	24	0.001
Hydropsyche brevis	15.2	0.001
Limnephilus (guadarramicus) sp.	10.5	0.001
Cheumatopsyche lepida	6.3	0.002
Orthotrichia angustella	4.9	0.003
Rhyacophila sp.	11.9	0.004
Hydropsyche sp1	6.7	0.004
Polycentropus sp.	14.4	0.017
Rhyacophila dorsalis	7	0.033
Allogamus sp.	5.1	0.034
Ithytrichia sp.	4	0.035
Hydropsyche bulbifera	2.6	0.048

CALCAREOUS/SEDIMENTARY LOWLAND RIVERS		
GROUP 5	IV-value	p-value
Hydropsyche exocellata	95.6	0.001
Ceraclea sp.	2.2	0.1081
Allotrichia pallicornis	0.9	0.3934
Rhyacophila sp.	6	0.5295

high significant of each group (p<0.01). *H. exocellata* is highly indicator and significant from calcareous/sedimentary lowland rivers, whereas other taxa also present in this group are not significant (*Ceraclea* sp., *A. pallicornis* and some *Rhyacophila* undetermined). Many caddisfly are characteristic from calcareous/siliceous headwaters located in medium altitude from northern basins, as *Sericostoma* sp., *H. siltalai*, *H. dinarica*, *Rh. dorsalis*, *H. radiatus, H. digitatus*, *Chaetopteryx* sp., *Limnephilus* sp. (mainly from *guadarramicus* species), *P. cingulatus* and *latipennis*. Some of these taxa are shared by siliceous headwaters in the highest areas of Sierra Nevada, as *Sericostoma* sp., *P. latipennis*, *P. montanus* and *Rh. meridionalis*. However, other caddisflies appear highly significant in group 2 rather than in group 1 as *H. instabilis*, *L. basalis*, *Rh. nevada, H. tesselatus* and others (Table 5). *Hydropsyche* gr. *pellucidula* has high IV-value in groups 3 and 4, being typical from midstreams reaches. Instead, other caddis as *Agapetus sp., M. aspersus, Rh. munda, H. infernalis, S. argentipunctellus and Stenophylax* sp. are exclusive from a more sedimentary-marl rather than calcareous basins. Midstream reaches with a dominant calcareous geology are significantly composed by *C. marginata*, *H. brevis*, *H.* gr. *pellucidula, H. sp1, H. bulbifera, O. angustella* and *C. lepida.* Other species present in this group 4 as *Rh. dorsalis* and *Limnephilus* sp. (*guadarramicus* type) are also characteristic from headwaters with similar geology (group 1).

Temporal patterns of distribution

When the effect of seasonality is analyzed using all samples, CCA plot (Figure 8) indicates a change of caddisfly taxa between seasons. Although the four first canonical axes explain only 5.9% of the caddisfly variability, Monte Carlo permutations test indicates that all canonical axes are significant when using seasonality (F=1.569, p-value=0.005). Several caddisflies remain present and frequent in all seasons, as for example, most of the Hydropsychidae, Hydroptilidae and Polycentropodidae. Trichopterans associated with some temporary sites as *G. pellucidus* or *Stenophylax* sp. appears present in winter and spring but not in summer. Other Limnephilidae (*H. radiatus*, *H. digitatus*, *Chaetopteryx* sp. or *Micropterna* sp. are found in spring samples. Summer and autumn seasons have few exclusive caddisfly, with some Brachycentridae and Psychomyiidae. Instead, many exclusive caddisfly are present between autumn and winter.

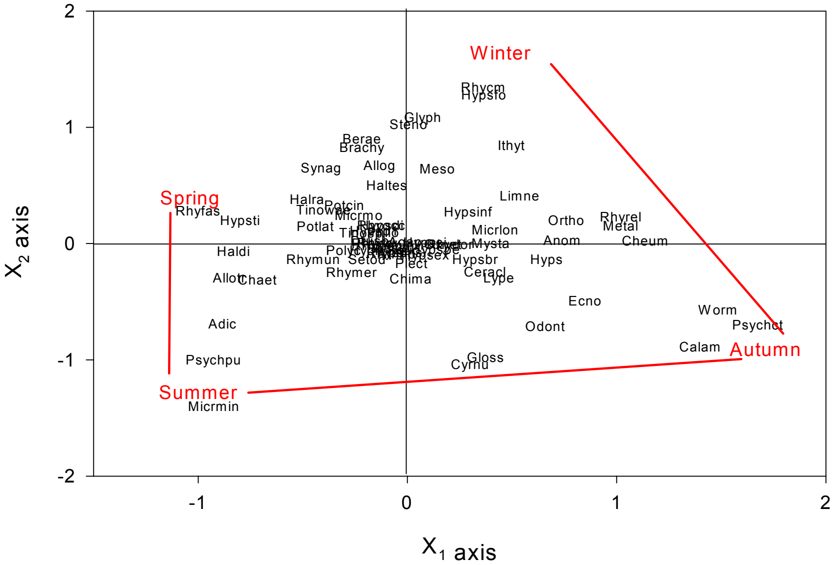


Figure 8. CCA plot representing taxa distribution in first (X_1) and second (X_2) axis using seasonality.

Relative effect of variables in caddisfly distribution

The variance partition results (Figure 9) indicate that environmental variables explain 20.8% of caddisfly distribution. From those, geomorphological features are the responsible of the major part of environmental variability (53.9%), followed by a mix of physical-chemical and biological community's characteristics. Temporality presents a low percentage explaining caddisfly communities. On the other hand, although significant, only 0.93% of trichoptera variation is explained by the seasonal effect. Interaction between environment and seasonality has also a weak importance in caddisfly distribution (0.2%). A high percentage of unexplained variables are noticed (78%).

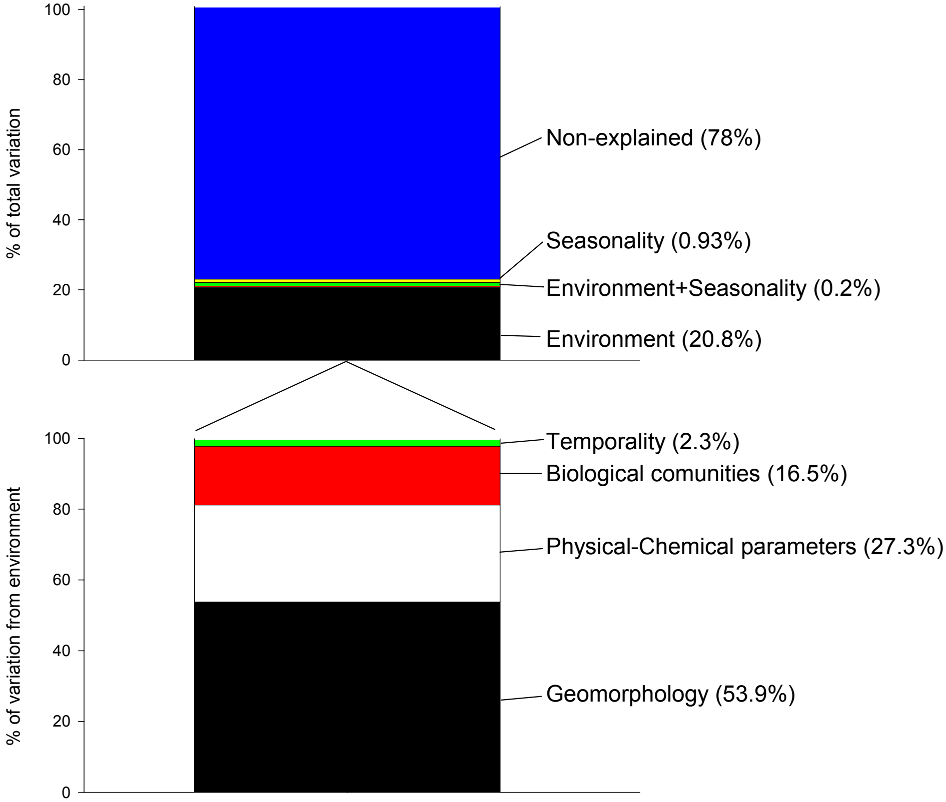


Figure 9. Variance partition with trichoptera data. Top graph present the percentages of all variation explained by environment and seasonality. Bottom graph present the total variation expressed by environment, separated by geomorphology (basin, riparian and habitat characteristics), physical-chemical variables, biological communities (IBMWP and IASPT) and temporality.

DISCUSSION

Observed patterns in caddisfly distribution in the Iberian Mediterranean area are spatial and temporal heterogeneous. Consequently, our results agree with the idea that distribution areas are dynamic structures (Antúnez & Mendoza, 1992), and they should be studied in a spatial-temporal framework using sets of multi-scale factors (Poff, 1997). Large-scale spatial filters (e.g., altitude) can change under large scale temporal ones (i.e., geological time). Instead, local scale features (e.g., discharge) are subjected to different temporal scales (i.e., from geological time to seasonality). All this assumption is very important in areas where climate is highly variable along and between years affecting discharge patterns and macroinvertebrate communities, as for example in mediterranean areas (McElravy *et al.*, 1989). For example, in other mediterranean areas (e.g., in southwestern Australia), macroinvertebrate community in permanent rivers has been found more persistent over time than temporary reaches (Bunn, 1995). In our study seasonality appears significant but only represents 0.93% of all caddisfly variability. Caddisfly larvae are more diverse between autumn, winter and spring than in summer, what may be explained by a high emergence of caddisfly species between June and September (e.g., Waringer, 1989). Most of the Hydropsychids are present in all seasons, except for the infrequent *H. tibialis* and *H. fontinalis, and H. infernalis* and *C. lepida* more abundant between autumn and winter (Gallardo-Mayenco *et al.*, 1998). Other taxa, as *M. aspersus* that present some summer strategies to avoid drought (Bouvet, 1974) is absent in summer period and very abundant between winter and spring.

In large scale studies performed in other areas in the world, geomorphological and other large-scale variables (e.g., climate) have been considered the major responsible of macroinvertebrate distribution (e.g., Ross, 1963; Corkum, 1989). However, this phenomenon has been related with the presence of a highly variable landscape and topography in the sampling area (Kay *et al.*, 1999; Wiberg-Larsen *et al.*, 2000). Mediterranean area has an abrupt topography (Conacher & Sala, 1998, Grove & Rackham, 2001) and landscape variables may play and important role structuring communities (Bonada *et al.*, Chapter 3). Trichoptera in Mediterranean Iberian coast is organized according to several variables acting at different scales in a hierarchical way. Geomorphological and landscape features (e.g., altitude, geology) are important to explain caddisfly distributions followed by reach (e.g., channel width, stream order, conductivity, riparian structure), habitat (e.g., riffles vs. pools, substrate diversity, heterogeneity elements) and biological characteristics. Overall, five different caddisfly communities defined by longitudinal zonation and geology (headwaters-midstreams-lowland and siliceous-calcareous-sedimentary reaches) have been established. Responses to caddisfly to these characteristics can be explained by feeding habits (Loudon & Alstad, 1990; Voelz & Ward, 1992), food quality (Petersen, 1987), metabolic needs (Hildrew & Edington, 1979), physical factors (Higler & Tolkamp, 1983; Tachet *et al.*, 1992) and chemical tolerance by natural (geology) (de Moor, 1992) or human-induced characteristics (Gallardo-Mayenco *et al.*, 1998; Stuijfzand *et al.*, 1999).

Geology has been considered as an important factor implied in caddisfly patterns and diversity in other areas (e.g., in South Africa —de Moor, 1992). In our case, geology is important to explain a general pattern of caddisfly distribution separating northern basins (mainly calcareous) from intermediate (predominantly sedimentary with marls) and southern ones (mainly siliceous). However, some caddisflies appear independent from geology and more dependent from longitudinal zonation. For example, *P. latipennis, Sericostoma sp., P. montanus* and *Rh. meridionalis* are shared between siliceous-calcareous headwaters and *H.* gr. *pellucidula* between calcareous-sedimentary midstreams. Moreover, Zamora *et al.* (1997) found *Rh. meridionalis* in the headwaters of a calcareous river in southeast Spain (Castril river), and Viedma & de Jalón (1980) in a siliceous area in Central Spain. Similarly, the Hydropsychid *H. instabilis* is not restricted to siliceous basins, because it has been collected in calcareous headwaters in southern France (Legier & Talin, 1973), and *Rh. munda* found mostly in sedimentary marls in our area has been collected in siliceous regions (Viedma & de Jalón, 1980; Ruiz *et al.*, 2001).

Traditionally, longitudinal zonation in streams has been related to slope and bed stability, water temperature and current velocity and some other stream hydraulics (see Statzner & Higler, 1986). Several studies have reported changes in macroinvertebrate composition downstream, associated to altitude, stream order, channel width… (e.g., Corkum, 1989; Marchant *et al.*, 1995; Wiberg-Larsen *et al.*, 2000). Marchant *et al.* (1995) suggest that altitude does not affect directly to the macroinvertebrates, but indirectly by changing water temperature, oxygen, discharge, nutrients, and others. In our study, altitude, channel width, stream order and their related variables as conductivity, biological quality, riparian structure, heterogeneity elements… are more important for trichopteran's longitudinal zonation than temperature, discharge or chemical parameters.

Headwater sites in Mediterranean areas (groups 1 and 2) are associated with the highest diverse, exclusive and infrequent caddisfly community, explained by a mix of substrates, heterogeneity elements and riparian structure. In fact, several authors have demonstrated a high correlation between spatial heterogeneity and organisms' diversity (Minshall & Robinson, 1998; Stewart *et al.*, 2000; Lawton, 2000). It is well known the effect of riparian vegetation organizing macroinvertebrate communities in river ecosystems (e.g., Molles, 1982; Aguiar *et al.*, 2002). We found that features directly or indirectly related to riparian forests are essential to explain patterns of some caddisflies species. A well-structured riparian vegetation (i.e., with trees and shrubs) yields a high amount of organic matter to the river beds (Iversen *et al.*, 1982) that can be retained depending on habitat characteristics (see Molles, 1982). In that sense, Canton & Ward (1981) in a study in a Colorado stream suggest that the absence of some shredders may be related to a decrease of inputs of leaf litter. In our study, the shredders and woody-cased (at least in some instars) caddisflies *L. guadarramicus*, *Halesus* sp., *Chaetopteryx* sp., *G. pellucidus* and *Potamophylax* sp. have been found significantly present in reaches with high riparian structure and heterogeneity elements (groups 1 and 5). These species disappear with increasing aridity (e.g., in Segura, Almanzora and Aguas basins (group 3)) where a high riparian structure and few heterogeneity elements may be related to the presence of a sclerophyllous and evergreen riparian forest. For example, Aguiar *et al.* (2002) in a study in a Portuguese basin under a mediterranean climate, found a positive relationship between ashes (*Fraxinus angustifolia*) and alders (*Alnus glutinosa*) with shredders but not with some sclerophyllous species. However, comparing caddisfly communities between deciduous and evergreen forests, Molles (1982) found a dominance of shredders in coniferous areas because habitat let a more retention of detritus.

Variables associated to the ecological river status (e.g., IBMWP, IASPT, riparian structure) also appear as discriminant variables between groups of sites with different caddisfly structure. Because the high diversification of Trichoptera (Mackay & Wiggins, 1979; Wiggins, 1984), they have been considered as a good indicators of water quality (Resh, 1992; de Moor, 1999; Stuijfzand *et al.*, 1999; Berlin & Thiele, 2002; Dohet, 2002; Waringer & Graf, 2002). *Hydropsyche exocellata* have been found in severe polluted sites in many studies (e.g., Higler & Tolkamp, 1983; Gallardo-Mayenco *et al.*, 1998) occupying lowland reaches (e.g., García de Jalón, 1986; Usseglio-Polatera, 1992), whereas *H.* gr. *Pellucidula, C. lepida* and the philopotamid *C. marginata* seem less tolerant to pollution appearing in middle reaches (Usseglio-Polatera, 1992; Moog & Chovarec, 2000; Bonada et al., Chapter 8), what agree with our study. However, in midstreams from sedimentary-marl basins, a very distinct assemblage is found with *M. aspersus, Rh. munda, H. infernalis* and *S. argentipunctellus* as a dominant species, what enhance the importance of these areas (called Ramblas) as ecological ecosystems (Moreno *et al.*, 1996; 2001). On the other hand, some of these species have been found in other reaches, as *S. argentipunctellus* recorded in upstream reaches over 1860 m in some Morocco streams (Guidicelli *et al.*, 1985), or *H. infernalis* that in the Iberian Peninsula has been recorded and in some headwaters (Gallardo-Mayenco et al., 1998) sometimes over 1000 m (Zamora-Muñoz *et al.*, 1995). Overall, longitudinal patterns displayed by Hydropsychidae correspond to the ones found in Duero Basin by García de Jalón (1986).

Although the large set of variables used a great amount of non-explained variability of species patterns is noticed. Around 74% of all collected caddisfly can be considered rare taxa (present in less than 5% of samples), which is common in macroinvertebrate communities' surveys (Lenat & Resh, 2001). Austin & Greig-Smith (1968) found that the percentage of variability explained in principal components analysis decreased with increasing the number of rare taxa included. In literature, disagreements exist in considering the use of rare taxa especially from a bioassessment point of view (Marchant, 1999; Cao & Williams, 1999; Cao *et al.*, 2001; Lenat & Resh, 2001). According to Cao *et al.* (2001), it is unlikely that rare caddisfly species respond to large-scale variables, but to local factors. For example, in our study, the infrequent *Calamoceras marsupus* is not an indicator caddisfly of any group of sites, although it appears related to several riparian features in the pCCA.

However, some other unconsidered factors may be important to understand this unexplained caddisfly patterns. Interactions between organisms have been considered to play an important role on the macroinvertebrate distribution in space and time (see Power *et al.*, 1988), but because they act in a smaller scale than abiotic processes, only can be detected if environment allow the presence of such organisms (Poff, 1997). Moreover, in a competition study in *Helicopsyche borealis* in a northern California creek, Lamberti *et al.*, (1987) suggested that a limitation on periphiton is the responsible of the intraspecific competition showed by larvae. Consequently, abiotic factors in a direct or indirect way acting at larger scales may be more important than biotic processes in structuring organism's patterns.

Historical factors have been widely neglected in ecological studies, although they have been considered one of the major factors affecting caddisfly distribution in other areas (de Moor, 1992). Iberian Mediterranean coast has been subjected to remarkable geological changes affecting present organism's distribution (Balletto & Casale, 1989). Probably, the most important phenomena were the incorporation of the Baetic-Riffian massif (the present south and south-east of Iberian Peninsula) to the Hesperico Massif, with the Alborán Plate rising at the end of Miocene (Martín-Piera & Sanmartín, 1999). Although the interchange of species with this new area was possible, nowadays a differentiation between southern and northern caddisfly in Iberian Peninsula is still noticed with a high component of North African species in the south and European ones in the north (González *et al.*, 1987; Ruiz *et al.*, 2001). This phenomenon could be the responsible to the mix of northern and southern species in Segura basin, yielding the highest taxa richness. Moreover, this historical factor also may play a significant role in explaining distribution of some caddisfly when samples from Pyrenees and Sierra Nevada (with similar environmental conditions) are compared. For example, several

Rhyacophila sp. are widely distributed in calcareous and siliceous headwaters in Pyrenees (e.g., *Rh. tristis*, *Rh. relicta, Rh. dorsalis*) but absent in Sierra Nevada. Contrarily, other species are exclusive from southern areas as *H. infernalis* or *Rh. nevada*, although this last one has been considered as a subspecies of *Rh. dorsalis* recently by Malicky (2002).

Organism's distribution is more or less heterogeneous at different spatial-temporal scales of observation (Kolasa & Rollo, 1991; Stewart *et al.*, 2000). When descriptions of distribution patterns are done at large scales to understand general processes implied, a loss of detail and some error have to be assumed (Levin, 1992) because patterns observed at larger scales might not correspond to others at small scale (Minshall, 1988). Results obtained here have inherent this assumption. Overall, caddisfly distribution in the Iberian Mediterranean area responds to longitudinal zonation factors and geological characteristics. However, geology is not as relevant for some caddisfly as zonation variables are, yielding an error in understanding general distribution patterns. A trade-off between all measured descriptors allow us to understand general patterns of distribution of all trichopteran assemblages, whereas some specific taxa distribution can respond to other regional or local factors as history or even random mechanisms (e.g., adult dispersion) and be independent of some general processes.

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Annex 1. QBR field sheet

QBR INDEX Riparian habitat quality

SECTION 1: Total riparian cover

Section 1 score

Score	
25	> 80 % of riparian cover (excluding annual plants)
10	50-80 % of riparian cover
5	10-50 % of riparian cover
0	< 10 % of riparian cover
+ 10	if connectivity between the riparian forest and the woodland is total
+ 5	if the connectivity is higher than 50%
- 5	connectivity between 25 and 50%
-10	connectivity lower than 25%

SECTION 2: Cover structure

Section 2 score

Score	
25	> 75 % of tree cover
10	50-75 % of tree cover or 25-50 % tree cover but 25 % covered by shrubs
5	tree cover lower than 50 % but shrub cover at least between 10 and 25 %
0	less than 10% of either tree or shrub cover
+ 10	at least 50 % of the channel has helophytes or shrubs
+ 5	if 25-50 % of the channel has helophytes or shrubs
+ 5	if trees and shrubs are in the same patches
- 5	if trees are regularly distributed and shrubland is > 50 %
- 5	if trees and shrubs are distributed in separate patches, without continuity
- 10	trees distributed regularly, and shrubland < 50 %

SECTION 3: Cover quality *(the geomorphological type should be first determined*)*

Section 3 score

Score		***Type 1***	***Type 2***	***Type 3***
25	number of native tree species:	> 1	> 2	> 3
10	number of native tree species:	1	2	3
5	number of native tree species:	0	1	1 - 2
0	absence of native trees	-		
+ 10	if the tree community is continuous along the river and covers at least 75% of the edge riparian area			
+ 5	the tree community is nearly continuous and cover at least 50% of the riparian area			
+ 5	if the riparian community is structured in gallery			
+ 5	when the number of shrub species is:	> 2	> 3	> 4
- 5	if there are some man-made buildings in the riparian area			
- 5	is there is some isolated species of non-native** trees			
- 10	presence of communities of non-native** trees			
- 10	presence of garbage			

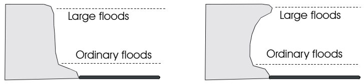
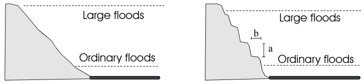
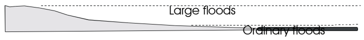
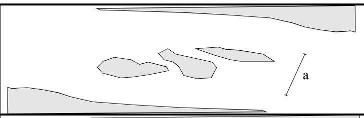
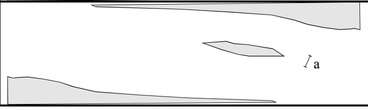
SECTION 4: Channel alteration

Section 4 score

Score	
25	unmodified river channel
10	fluvial terraces modified and constraining the river channel
5	Channel modified by rigid structures along the margins
0	channelized river
- 10	river bed with rigid structures (e.g wells)
- 10	transverse structures into the channel (e.g weirs)

Final score (sum of four section scores)

*** Type of the riparian habitat (to be applied at level 3, cover quality)**
The score is obtained by addition of the scores assigned to left and right river margins according to their slope. This value can be modified if islands or hard substrata are present.

Slope and form of the riparian zone		***Score*** Left	Right
Very steep, vertical or even concave (slope > 75º), very high, margins are not expected to be exceeded by floods.*Slope is the angle subtended by the line between the top of the riparian area and the edge of the ordinary flooding of the river.*		**6**	**6**
Similar to previous category but with a bankfull which differentiates the orditary flooding zone from the main channel.		**5**	**5**
Slope of the margins between 45 and 75 º, with or without steps. (a > b)		**3**	**3**
Slope between 20 and 45 º, with or without steps. (a < b)		**2**	**2**
Slope < 20 º, large riparian zone.		**1**	**1**
Presence of one or several islands in the river			
Width of all the islands "a" > 5 m.		- 2	
Width of all islands "a" < 5 m.		- 1	

Percentage of hard substrata that can made impossible the presence of plants with roots.	
> 80 %	Not applicable
60 - 80 %	+ 6
30 - 60 %	+ 4
20 - 30 %	+ 2
Total Score	

Geomorphological type according to the total score

> 8	**Type 1**	Closed riparian habitats. Riparian trees, if present, reduced to a small strip. Headwaters.
5 to 8	**Type 2**	Headwaters or midland riparian habitats. Forest may be large and originally in gallery.
< 5	**Type 3**	Large riparian habitats, and potentially extensive forests. Lower courses.

Annex 2. IHF field sheet

Evaluación del Hábitat Fluvial para Ríos Mediterráneos. Índice IHF

Bloques			**Puntuación**	
1. Inclusión rápidos-sedimentación pozas				
Rápidos	Piedras, cantos y gravas no fijadas por sedimentos finos. Inclusión 0 - 30%.		10	
	Piedras, cantos y gravas poco fijadas por sedimentos finos. Inclusión 30 - 60%.		5	
	Piedras, cantos y gravas medianamente fijadas por sedimentos finos. Inclusión > 60%.		0	
Sólo pozas	Sedimentación 0 - 30%		10	
	Sedimentación 30 - 60%		5	
	Sedimentación > 60%		0	
		TOTAL (una categoria)		
2. Frecuencia de rápidos				
	Alta frecuencia de rápidos. Relación distancia entre rápidos / anchura del río < 7		10	
	Escasa frecuencia de rápidos. Relación distancia entre rápidos / anchura del río 7 - 15		8	
	Ocurrencia ocasional de rápidos. Relación distancia entre rápidos / anchura del río 15 - 25		6	
	Constancia de flujo laminar o rápidos someros. Relación distancia entre rápidos/anchura del río >25		4	
	Sólo pozas		2	
		TOTAL (una categoria)		
3. Composición del substrato				
	% Bloques y piedras	1 - 10%	2	
		> 10%	5	
	% Cantos y gravas	1 - 10%	2	
		> 10%	5	
	% Arena	1 - 10%	2	
		> 10%	5	
	% Limo y arcilla	1 - 10%	2	
		> 10%	5	
		TOTAL (sumar categorías)		
4. Regímenes de velocidad / profundidad				
somero:< 0.5 m	4 categorías. Lento-profundo, lento-somero, rápido-profundo y rápido-somero.		10	
lento:< 0.3 m/s	Sólo 3 de las 4 categorías		8	
	Sólo 2 de las 4		6	
	Sólo 1 de las cuatro		4	
		TOTAL (una categoría)		
5. Porcentaje de sombra en el cauce				
	Sombreado con ventanas		10	
	Totalmente en sombra		7	
	Grandes claros		5	
	Expuesto		3	
		TOTAL (una categoría)		
6. Elementos heterogeneidad				
	Hojarasca	> 10% ó < 75%	4	
		< 10% ó > 75%	2	
	Presencia de troncos y ramas		2	
	Raíces expuestas		2	
	Diques naturales		2	
		TOTAL (sumar categorías)		
7. Cobertura de vegetación acuática				
	% Plocon + briófitos	10 - 50%	10	
		< 10% ó > 50%	5	
	% Pecton	10 - 50%	10	
		< 10% ó > 50%	5	
	% Fanerógamas + Charales	10 - 50%	10	
		< 10% ó > 50%	5	
		TOTAL (sumar categorías)		
		PUNTUACIÓN FINAL (suma de las puntuaciones anteriores)		

Annex 3. Taxa's codes

CODE	TAXA
Adic	*Adicella* sp.
Agap	*Agapetus* sp.
Allog	*Allogamus* sp.
Allotr	*Allotrichia pallicornis*
Anom	*Anomalopterygella chauviniana*
Drusb	*Drusus bolivari*
Athrip	*Athripsodes* sp.
Berae	*Beraea* sp.
Brachy	*Brachycentrus (O.) maculatum*
Calam	*Calamoceras marsupus*
Ceracl	*Ceraclea* sp.
Chaet	*Chaetopteryx* sp.
Cheum	*Cheumatopsyche lepida*
Chima	*Chimarra marginata*
Cyrnu	*Cyrnus* sp.
Ecno	*Ecnomus* sp.
Gloss	*Glossosoma* sp.
Glyph	*Glyphotaelius pellucidus*
Haldi	*Halesus digitatus*
Halra	*Halesus radiatus*
Haltes	*Halesus tessellatus*
Hypsbr	*Hydropsyche brevis*
Hypsbu	*Hydropsyche bulbifera*
Hypsfo	*Hydropsyche fontinalis*
Hypsdi	*Hydropsyche dinarica*
Hypsex	*Hydropsyche exocellata*
Hypspe	*Hydropsyche* gr. *pellucidula*
Hypsinf	*Hydropsyche infernalis*
Hypsins	*Hydropsyche instabilis*
Hypssi	*Hydropsyche siltalai*
Hyps	*Hydropsyche* sp.
Hypsp1	*Hydropsyche sp1*
Hypsti	*Hydropsyche tibialis*
Hydrt	*Hydroptila* sp.
Ithyt	*Ithytrichia* sp.
Lasio	*Lasiocephala basalis*

CODE	TAXA
Limne	*Limnephilus* sp. *(guadarramicus)*
Lype	*Lype reducta*
Meso	*Mesophylax aspersus*
Metal	*Metalype fragilis*
Micrlon	*Micrasema longulum*
Micrmin	*Micrasema minimum*
Micrmo	*Micrasema moestum*
Mysta	*Mystacides azurea*
Odont	*Odontocerum albicorne*
Ortho	*Orthotrichia angustella*
Oxyet	*Oxyethira* sp.
Philo	*Philopotamus montanus*
Plect	*Plectrocnemia* sp.
Polyc	*Polycentropus* sp.
Potcin	*Potamophylax cingulatus*
Potlat	*Potamophylax latipennis*
Psychct	*Psychomyia* cf. *ctenophora*
Psychpu	*Psychomyia pusilla*
Rhycm	*Rhyacophila* cf. *munda*
Rhyocc	*Rhyacophila* cf. *occidentalis*
Rhytri	*Rhyacophila* gr. *tristis*
Rhydor	*Rhyacophila dorsalis*
Rhyfas	*Rhyacophila fasciata denticulata*
Rhymer	*Rhyacophila meridionalis*
Rhymun	*Rhyacophila munda*
Rhynev	*Rhyacophila nevada*
Rhyrel	*Rhyacophila relicta*
Rhysp	*Rhyacophila* sp.
Seric	*Sericostoma* sp.
Setod	*Setodes argentipunctellus*
Steno	*Stenophylax* sp.
Synag	*Synagapetus* sp.
Tinosp	*Tinodes* sp.
Tinowae	*Tinodes waeneri*
Worml	*Wormaldia* sp.

Chapter 8

OPTIMUMS AND ECOLOGICAL PROFILES OF CADDISFLIES FROM MEDITERRANEAN STREAMS

INTRODUCTION

The study of relationships between organisms and environmental variables has been the major goal to be achieved by applied freshwater ecologists to predict and determine water quality (e.g., see Cairns & Pratt, 1993). Very often in applied hydrology, organisms are qualified as tolerant or sensitive without detailed studies about its sensitivity to pollution and is not easily to found a specific quantification of their tolerance to different environmental variables (Verdonschot & Higler, 1992; Lenat & Resh, 2001). Several statistical procedures, based in the idea that the abundances of organisms along an environmental gradient follow a unimodal distribution (Whittaker, 1967), have been developed to estimate taxa optimums and tolerances in front of several environmental variables (e.g., Ter Braak & Looman, 1986; Ter Braak & Van Dam, 1989; Juggins, 1997). These methods have been extensively used in Paleolimnology to infer past environmental conditions (e.g., Ter Braak & Van Dam, 1989; Birks *et al.*, 1990; Bigler & Hall, 2002). However, although recent multivariate models (e.g., RIVPACS, AusRivAS) designed to assess water quality include this idea of quantifying ecological requirements of macroinvertebrate communities (Wright *et al.*, 1989; Wright, 1995; Smith *et al.*, 1999), few studies report specific optimums and tolerances of macroinvertebrate taxa (but see Verdonschot

& Higler, 1992). Ecological profiles for macroinvertebrate taxa are required to test effectiveness of biological indexes and to determine indicator species and autoecological information from environmental conditions (Moretti & Mearelli, 1981). Indicator species have specific requirements to several variables (Johnson *et al.*, 1993) that can vary in a higher taxonomic resolution (Resh & Unzicker, 1975; Cranston, 1990), and for this reason, several authors suggest to take caution in the use of higher taxonomic levels in bioassessment methods (as families) (e.g., Moog & Chovarec, 2000). Today, numerous controversies exist in literature in the taxonomic sufficiency to be used because ecological patterns showed by species and families may be similar using all the community (Furse *et al.*, 1984; Marchant, 1990; Rutt *et al.*, 1993; Hewlett, 2000).

At family, species and individuals level, Trichoptera have been considered as an appropriated group to assess water quality using larvae (e.g., see Resh, 1992; De Moor, 1999; Stuijfzand *et al.*, 1999; Bonada *et al.*, Chapter 9) or adults (Malicky, 1981; Usseglio-Polatera & Bournaud, 1989). In a study in Luxembourg Rivers, Dohet (2002) found that Trichoptera were more appropriated for bioassessment than Ephemeroptera, Coleoptera or Plecoptera. Factors as their ubiquity, diversity, biological and ecological characteristics and the simplicity of their sampling may explain this (Mackay & Wiggins, 1979; de Moor, 1999; Waringer & Graf, 2002). At family and species levels, caddisfly have been related to several environmental variables displaying some specific trends in ecological requirements (e.g., Dohet, 2002; Bonada *et al.*, Chapter 7) without establishing optimums and tolerance ranges. Caddisfly ecological profiles can be obtained from literature from several ways. From one hand, studies performed in deformities (Décamps *et al.*, 1973; Petersen & Petersen, 1983; Camargo, 1991; Vuori, 1995; Vuori & Kukkonen, 2002), asymmetries (Bonada & Williams, 2002) or toxicity tests (Greve *et al.*, 1998) may allow us to infer optimums and tolerances for a single species. On the other hand, studies performed using large sets of field data including several species can also be useful (e.g., Gordon & Wallace, 1975; Moretti & Mearelli, 1981; Herranz & García de Jalón, 1984; Verdonschot & Higler, 1992; Stuijfzand *et al.*, 1999; Kay *et al.*, 2001). However, most of these studies usually are done in small areas, with insufficient data, or without taking into account the abundance of organisms, and thereby some cautions should be taken in extrapolating these results to other areas or taxonomical levels.

In this study, caddisflies ecological profiles have been studied from field data obtained in streams of the Iberian Mediterranean coast. Four factors make the caddisflies in this area an ideal group to study their ecological profiles to water quality variables. Firstly, the high diversity and endemicity of caddisfly in the Iberian Peninsula because interactions between ecological and historical factors, (González *et al.*, 1987) with 331 species (Vieira-Lanero, 2000 plus González & Ruiz, 2001 and Zamora-Muñoz *et al.*, 2002 —see Bonada *et al.*, Chapter 6). Secondly, the harsh natural abiotic conditions in these mediterranean ecosystems (see Bonada *et al.*, Chapter 3) that may yield to a high diversification of ecological profiles of trichopterans. Third, the lack of information about autoecology studies of caddisflies in Mediterranean areas, except the obtained from taxonomical papers (Bonada *et al.*, Chapter 6). Finally, the significant river alteration in the Mediterranean area by human impact (Prat, 1993) implies the presence of a variety of reaches subjected to different water quality where optimums and tolerances of caddisflies can be studied.

The objectives of the present chapter are: (1) to determine optimums and tolerances of caddisfly taxa for several ecological variables at different taxonomical resolution and (2) to calculate ecological profiles for each taxon and to evaluate their sensitivity.

METHODOLOGY

Sampling area

Ten basins from the Mediterranean coast in east Spain were sampled (Figure 1): Besòs, Llobregat, Mijares, Turia, Júcar, Segura, Almanzora, Aguas, Adra and Guadalfeo (an extensive description of sampled basins can be found in Robles *et al.*, in prep). The area is subjected to mediterranean climate (Köppen, 1923), with a significant spring and autumn rainfall. Limestone and sedimentary materials mainly compose geology, although some siliceous areas are also present as Sierra Nevada, Pyrenees and Montseny ranges (Figure 1). Sclerophyllous and evergreen trees and shrubs mainly compose basin vegetation, although in some medium and high altitude areas deciduous and coniferous forests are present.

Because of the seasonality of the climatic patterns and the variability in landscape, topography and geomorphology, rivers in the sampled basins are highly variable in space and time. Overall, sampled rivers are subjected to high annual discharge variability, more or less important depending on the local conditions, with frequent floods and droughts (Molina *et al.*, 1994; Gasith & Resh, 1999). In space, a high variability of rivers have been sampled (Bonada *et al.*, in press-a): alpine, siliceous and short rivers from Sierra Nevada, longer and calcareous rivers from Pyrenees and Iberian Ranges; small rivers and tributaries with a temporary condition to karstic streams and saline ramblas in the south-east.

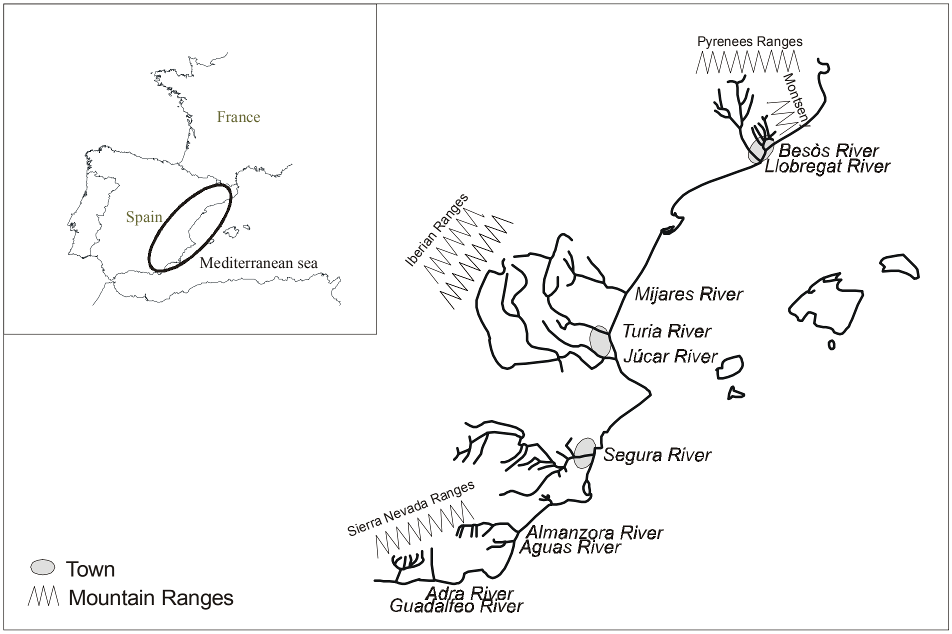


Figure 1. Basins sampled along Spanish Mediterranean coast.

As in other mediterranean regions, sampled basins have been largely affected by human activities (Trabaud, 1981) as agriculture, cattle, urbanization, salinization, water abstraction and regulation... (Conacher & Sala, 1998). All these factors have contributed to the river alteration in a direct or indirect way (Prat, 1993).

Sampling sites

A total of 157 sampling sites have been surveyed along Iberian Mediterranean coast four times in 1999 (spring, summer, autumn and winter) and three times in 2000 (spring, summer and autumn). They are part of the GUADALMED Project to assess the ecological status of the Spanish mediterranean rivers according to the Water Frame Directive (European Parliament and Council, 2000). Sites are more or less equally distributed among all basins, and they include reference and non-reference sites (see Bonada *et al.*, in press-b). The variety of sampled river types and reaches subjected to different local climates and landscape characteristics, implies the presence of different riparian communities with reaches without a structured riparian vegetation by natural conditions (i.e., ramblas and ephemeral rivers) to well preserved riparian forests in the headwaters of main rivers or tributaries (Suárez *et al.*, in press). However, the high human activities present in the sampled basins imply an extreme human alteration of riparian areas (Prat *et al.*, 1999) with numerous species introductions as *Platanus hispanica, Populus* *deltoides*, *Robinia pseudoacacia* and *Nicotiana sp.*. However, in some reference and permanent headwaters, communities of *Salix alba*, *Corylus avellana, Populus nigra and Populus alba* are dominant. Sampling sites present a high variability in substrate types that enable the presence of abundant instream vegetation (e.g., mosses, diatoms, zygnematales and *Cladophora* sp.) and macrophytes (e.g., *Apium nodiflorum*, *Veronica* sp., *Rorippa* sp. and *Chara* sp.).

Sampling procedure

Sites were sampled following GUADALMED Protocol (Jáimez-Cuéllar, in press; Bonada *et al.*, Chapter 1) designed as a bioassessment method, but the fine mesh size used and the absence of sampling restrictions comparing with other procedures, allow us the use of this Rapid Bioassessment Protocol in macroinvertebrate community studies (Bonada *et al.*, Chapter 2).

The environmental variables considered in this study are oxygen and conductivity (directly measured in the field) and ammonium, N-nitrites, P-phosphates, suspended solids, sulphates and chloride, that were analyzed in the lab using the methods exposed in Toro *et al.* (in press). Also, the riparian quality was measured using QBR index (Munné *et al.*, 1998; in press; Suárez & Vidal-Abarca, 2000). The sinecological value of the entire macroinvertebrate community was introduced by the IBMWP index, which also informs about the water quality.

Macroinvertebrate samples were collected in riffles and pools with a kick-net of 250 µm mesh size. Samples were firstly examined in the field, and successive samples in both habitats were taken until no more families were found, to collect the maximum sample representativeness of taxa richness. Several invertebrates seen in the field but not taken in the sample were also recorded, as the large Heteroptera and Coleoptera. Samples were preserved in alcohol 70% and sorted in the lab. The biological index IBMWP (Alba-Tercedor & Sánchez-Ortega, 1988; Alba-Tercedor, 1996; Alba-Tercedor & Pujante, 2000) was recorded for each site and season. Caddisfly taxa were identified at the maximum level possible, and rank of abundances was recorded for each taxon: 1 from 1-3 individuals, 2 from 4-10, 3 from 11-100 and 4 for more than 100 individuals. Because the large amount of undescribed larvae in the Iberian Peninsula (Vieira-Lanero, 2000) we were not able to identify all taxa at species level with certainty. When it was possible pupae and adults were collected in the field to ensure larvae identifications. Moreover, in some cases mature larvae were reared in the lab using a system inspired in Vieira-Lanero (1996). Identified caddisfly data obtained from all sampling seasons were selected to check for optimums and tolerances under different environmental variables. In total, 3423 records were used, corresponding to 13 different families and 41 taxa at genus or species level depending on their degree of confidence in the identification and their frequency (see Annex 1). Taxa used were present in 10 or more records.

Data analysis

A Weighted Average Regression was performed with the CALIBRATE vs0.7 program (Juggins, 1997) to calculate the optimums and tolerances for all caddisflies (13 families and 41 genus/species) using environmental data obtained (Table 1). This analysis estimates the optimum of an environmental variable of each species using the average of the values of the variable where taxa are present, weighted by the species' relative abundance (Birks *et al.*, 1990). Consequently, the optimum of a species is referred to the environmental conditions with its highest relative abundance and tolerance is equivalent to the standard deviation from the optimum. Weighted regression (to estimate the taxon's optima) and calibration (to infer the environmental data using the optima of all taxa present in the sample) have been widely applied in paleolimnology to infer environmental conditions using optimums and tolerances of diatoms species (e.g., Birks *et al.*, 1990; Bigler & Hall, 2002).

To interpret the optimums and tolerances of each taxon for each environmental variables, the reference values for biotic and riparian indexes and several chemical characteristics from Prat *et al.* (2000 and 2001) have been used and are presented in Annex 2.

Table 1. Variables measured and used in the analysis.

Variable	Considerations
NH_4^+	Concetration in mg/l of NH4+
$N\text{-}NO_2^-$	Concetration in mg/l of N-NO2-
$P\text{-}PO_4^{3-}$	Concentration in mg/l of P-PO43-
SO_4^{2-}	Concetration of sulfates in mg/l
Cl^-	Concentration of chloride in mg/l
SS	Suspended solids in mg/l
O2	Oxygen in mg/l
QBR	Index of Riparian Vegetation Quality (Munné et al., 1998)
IBMWP	Biological index for water quality (Alba-Tercedor & Sánchez-Ortega, 1988)
IASPT	Relationship between IBMWP and number of families

RESULTS

Optimums and tolerances of caddisflies families

A general pattern can be observed when caddisflies families are arranged according to their optimum values (Figure 2). Brachycentridae, Sericostomatidae, Lepidostomatidae and Odontoceridae are exclusive from high water quality and good ecological conditions. In contrast, Glossosomatidae, Hydropsychidae and Hydroptilidae have the optimum in lower values of biologic and riparian indices and higher chemical parameters concentration.

Overall, caddisflies families present IBMWP optimums over than 100, indicating that they tend to be present in reaches with very good biological quality. Hydropsychidae, Hydroptilidae and Lepidostomatidae are more frequent at lower biological indexes whereas, families as Brachycentridae or Sericostomatidae present the maximum of their abundance at higher values of biological quality index. A similar pattern is observed in the QBR index, with Lepidostomatidae preferring higher values of riparian quality index respect Hydropsychidae and Hydroptilidae. In contrast, Glossosomatidae that have the maximum of abundance at intermediate IBMWP prefers a fair riparian quality. No caddisflies have the optimum in QBR values corresponding to a poor or very poor riparian quality. Oxygen concentration optimums and tolerances for caddisflies are similar between families, with values around 10 mg/l and tolerances between 7 and 13 mg/l.

Optimums and tolerances for chemical parameters may follow different patterns for different families. Overall, families with higher optimums values for a variable can tolerate a wider range of chemical concentrations than taxa with lower optimums values. For ammonium, Brachycentridae, Lepidostomatidae, Leptoceridae and Philopotamidae present optimums typical from clean waters with less than 0.1 mg/l, whereas the rest of families are more frequent at concentrations between 0.1 and 0.25 mg/l. Hydropsychidae and Hydroptilidae although having the optimum lower than 0.4 mg/l, can be present until almost 0.9 mg/l, tolerating waters subjected to an important chemical stress. A similar pattern is observed in N-nitrites concentration with all families presenting the optimum at less than 0.3 mg/l, and Hydropsychidae, Glossosomatidae, Hydroptilidae, Rhyacophilidae, Brachycentridae and Odontoceridae tolerating concentrations, until 0.58 mg/l in Hydropsychidae.

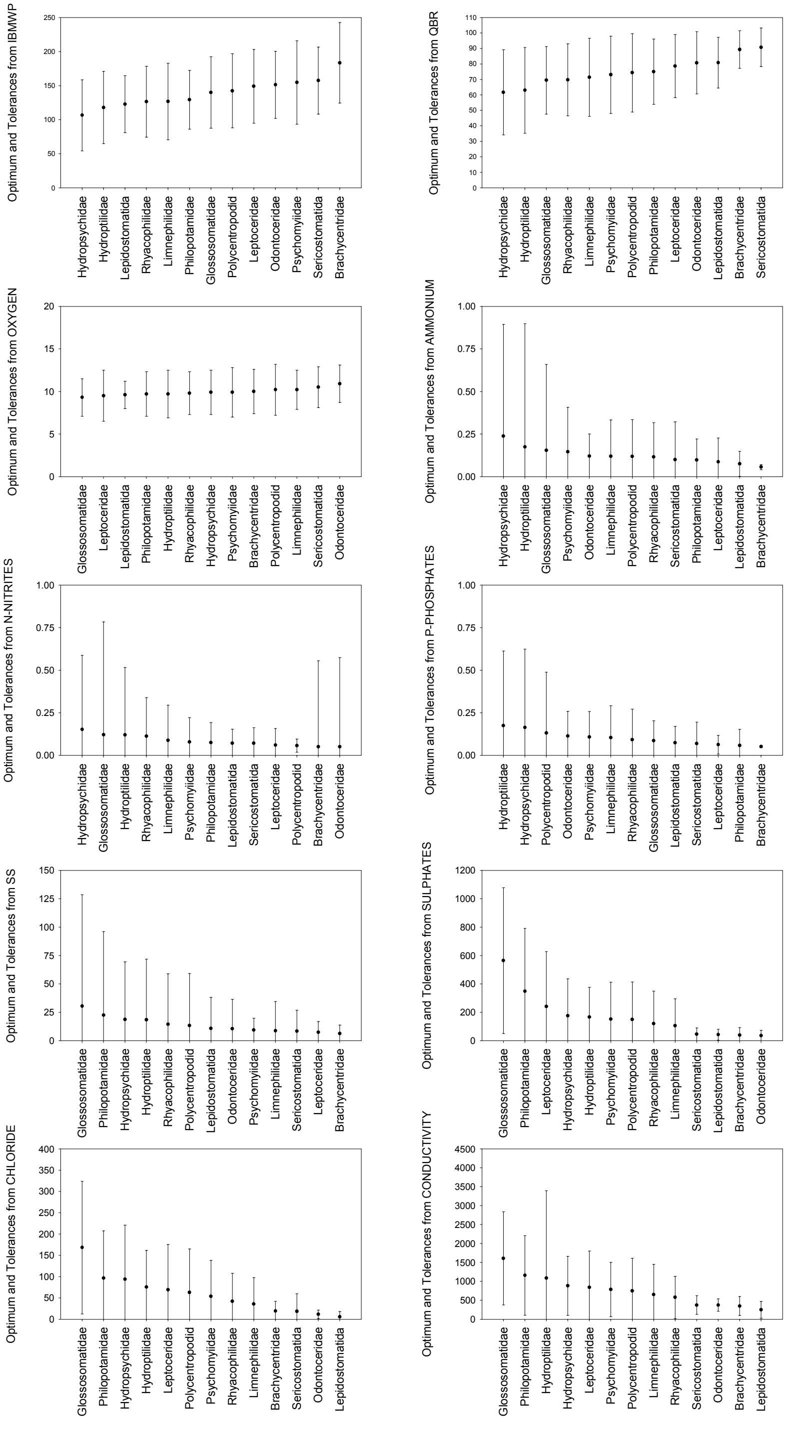


Figure 2. Scatter plots of optimums with error bars indicating the standard deviation (equivalent to the tolerance) of caddisfly families. X axes are arranged according to increasing optimum in IBMWP, QBR and oxygen and decreasing in ammonium, N-nitrites, P-phosphates, suspended solids, sulphates, chloride and conductivity.

All caddisflies have maximum abundances at levels under 0.03 mg/l of P-phosphates indicating that they prefer clean water without eutrophy. Only, Hydroptilidae, Hydropsychidae and Polycentropodidae appear more tolerant with maximum values of tolerance around 0.5 mg/l. Glossosomatidae present a low optimum in P-phosphates but high in ammonium and N-nitrites, indicating a high sensitivity to eutrophy. Optimums on high suspended solids concentrations correspond to families with species characteristics from midstreams and lowland rivers as Glossosomatidae, Philopotamidae and the filter-feeder Hydropsychidae (see Bonada *et al.*, Chapter 7). In contrast, some headwater families as Brachycentridae and Sericostomatidae have maximum abundances at low suspended solid concentrations with a narrow range of tolerance.

All chemical measurements related to salinity conditions present a similar pattern, indicating a strong relationship between chloride, sulphates and conductivity with basin geology (Toro *et al.*, in press). Philopotamidae, that for the other parameters occupied an intermediate position is more abundant at higher values of sulphates, suspended solids, chloride and conductivity than other families. Leptoceridae also appear very abundant in high chloride concentrations and conductivity, although is unable to tolerate high concentrations of suspended solids, P-phosphates, N-nitrites and ammonium. Concentrations of sulphates over than 250 mg/l may be related to pollution or to the presence of gypsum in the basin. Glossosomatidae and Philopotamidae have the optimum in these conditions followed by some leptocerids. Other families have the optimum under 250 mg/l but can tolerate up to 400 mg/l, as Hydropsychidae, Psychomyiidae, Polycentropodidae and Rhyacophilidae. Similarly, high chloride concentrations may be present by pollution or be natural, and Glossosomatidae, Philopotamidae, Hydropsychidae, Hydroptilidae and Leptoceridae have the maximum abundances between 69 and 168 mg/l. The high values of conductivity achieved by some families that are abundant in high IBMWP score, as Glossosomatidae or Philopotamidae, indicate the presence in our set of dates of reaches with natural salinity (e.g., sedimentary marls). Thus, Glossosomatidae is very abundant at 1606µS/cm and tolerates until 2800 µS/cm. Hydroptilidae appears as the most tolerant family because it can be present until values up to 3300 µS/cm. In contrast, Lepidostomatidae, Brachycentridae, Odontoceridae and Sericostomatidae have the optimum around 300 µS/cm and a narrow range of tolerance.

Optimums and tolerances of caddisflies genus/species

Looking at the species or genus within families, some different patterns may be observed (Figure 3, 4 and 5). IBMWP index present the optimum over 100 in all species except for *H. exocellata* with 65.6 value and a tolerance going from 31.7 to 99.5. Many species have their maximum of abundance over 100 but can tolerate moderately polluted waters as *L. guadarramicus*, *C. marginata, Stenophylax* sp., *H. infernalis*. Instead, *H. dinarica, Micrasema* sp., *Rh.* gr. *tristis, P. cingulatus, P. kingi* and *Allogamus* sp., only tolerate a very good water quality. A similar species arrangement is observed for QBR index (Figure 3). *H. exocellata* and *M. aspersus* have the maximum of abundance in reaches with a poor riparian quality, whereas other species prefer well preserved riparian forest as *Allogamus* sp., *Potamophylax* sp., *Micrasema* sp. and *P. montanus*. As in families, oxygen optimums and tolerances are similar between species (Figure 3), with many caddisflies having optimums over 10mg/l (e.g., *P. flavomaculatus, H. dinarica, H. siltalai, M. azurea*).

Except few species, caddisflies are very sensitive to toxicity by ammonium (Figure 4). *H. exocellata* is the more tolerant species having the optimum at 0.59 mg/l and able to tolerate until 2 mg/l. Other species as *H. radiatus*, *Sericostoma* sp., *H. sp1* and *Hydroptila* sp. present the maximum of abundance in water with some stress and even may tolerate concentrations over 0.4 mg/l. *Agapetus* sp., a very abundant Glossosomatidae, present a wide range of tolerance to ammonium, whereas *A. chauviniana, Ithytrichia* sp., *Micrasema* sp. and *H. tesselatus* are very sensitive to this toxic. *Hydropsyche* gr. *pellucidula*, that have the optimum at low values of riparian vegetation is very intolerant to ammonium but can be present at concentrations of N-nitrites over than 0.3 mg/l. A similar pattern is observed with *Chaetopteryx* sp. which appears as the species more tolerant to N-nitrites, having the optimum at 0.32 mg/l, but intolerant to ammonium. The rest of species present optimums of N-nitrites between 0.03-0.3mg/l, although, surprisingly, most of them are able to survive in a wide range of N-nitrites concentration. Looking at the P-phosphates (Figure 4), *H. exocellata* is the most tolerant species with the optimum in reaches with high eutrophy, and able to tolerate very high concentrations. Instead, many species have the maximum of abundance between 0.03 and 0.09 mg/l and few can tolerate eutrophy. *C. lepida, H. dinarica, M. longulum* and *Rh. meridionalis* although having the optimum at very low P-phosphates concentrations can tolerate a wide range of concentrations, appearing independently of eutrophy. Optimums and tolerances for suspended solids and salinity measurements are plotted in Figure 5. At species level, some differences can be observed from the patterns showed by families in Figure 2. The predator *Rh. munda* is the caddisfly more tolerant to solids with it maximum of abundance in 38.4 mg/l, followed by some filter-feeding Hydropsychids, *P. kingi* and *C. marginata*. Most of the species have the optimum in quite clear waters with levels of suspended solids under 25 mg/l, and the headwater caddisfly *H. dinarica* appears as the less tolerant to suspended particles. Caddisfly species arrangement in salinity parameters is similar. *Agapetus* sp. is the species with the higher optimum in sulphates, chloride and conductivity, followed by *S. argentipunctellus, C. marginata* and some

Hydropsychids (e.g., *H. exocellata, H. brevis, H. infernalis, H.* gr. *pellucidula*). Most of the caddisflies have the optimums at sulphates concentrations under 250 mg/l, indicating their preferences for basins without gypsum geology, as *Micrasema* sp., *Sericostoma* sp. or *Halesus* sp. The glossosomatid *Agapetus* sp. is very frequent in chloride concentrations over than 200 mg/l and conductivities of 1802 μS/cm. However, *Hydroptila* sp. although having the optimum of sulphates and chloride under 250 mg/l and 99 mg/l respectively, presents the widest tolerance to conductivity, beeing able to survive at more than 4000 μS/cm.

Ecological profiles for caddisfly taxa

Ecological profiles for each genus/species and family levels have been figured out using tolerances for six measured environmental variables (oxygen, suspended solids, P-phosphates, ammonium, sulphates and chloride) (Figures 6, 7, 8, 9 and 10). N-nitrites have been omitted because the high tolerance values in some species with low optimums, what could be an error in chemical analysis. Profiles have been drawn as a polyhedral figure (Figure 6). Each axis represents the tolerance range constrained between 1 and 0. The extremes of each axis indicate the intolerance of taxa to high values of chemical parameters (i.e., suspended solids, P-phosphates, ammonium, sulphates and chloride) or to low values of oxygen. When combining the tolerance ranges for all axes a shaded figure appears indicating the degree of tolerance for each taxon, whereas the non-shaded area displays the degree of intolerance to pollution. Thereby, caddisfly very sensitive to all environmental variables will have narrow shade and large empty areas, in contrast to very tolerant taxa. The degree of intolerance score (DIS) has been measured using the following formula:

$$\mathrm{DIS}= \sum_{i=1}^{5} (1-\max_i) + \min_j$$

for i=chemical variables and j=oxygen concentration

This score varies between 0 to 6 and give us an idea of the sensitivity of each species to pollution (higher the value, more intolerant).

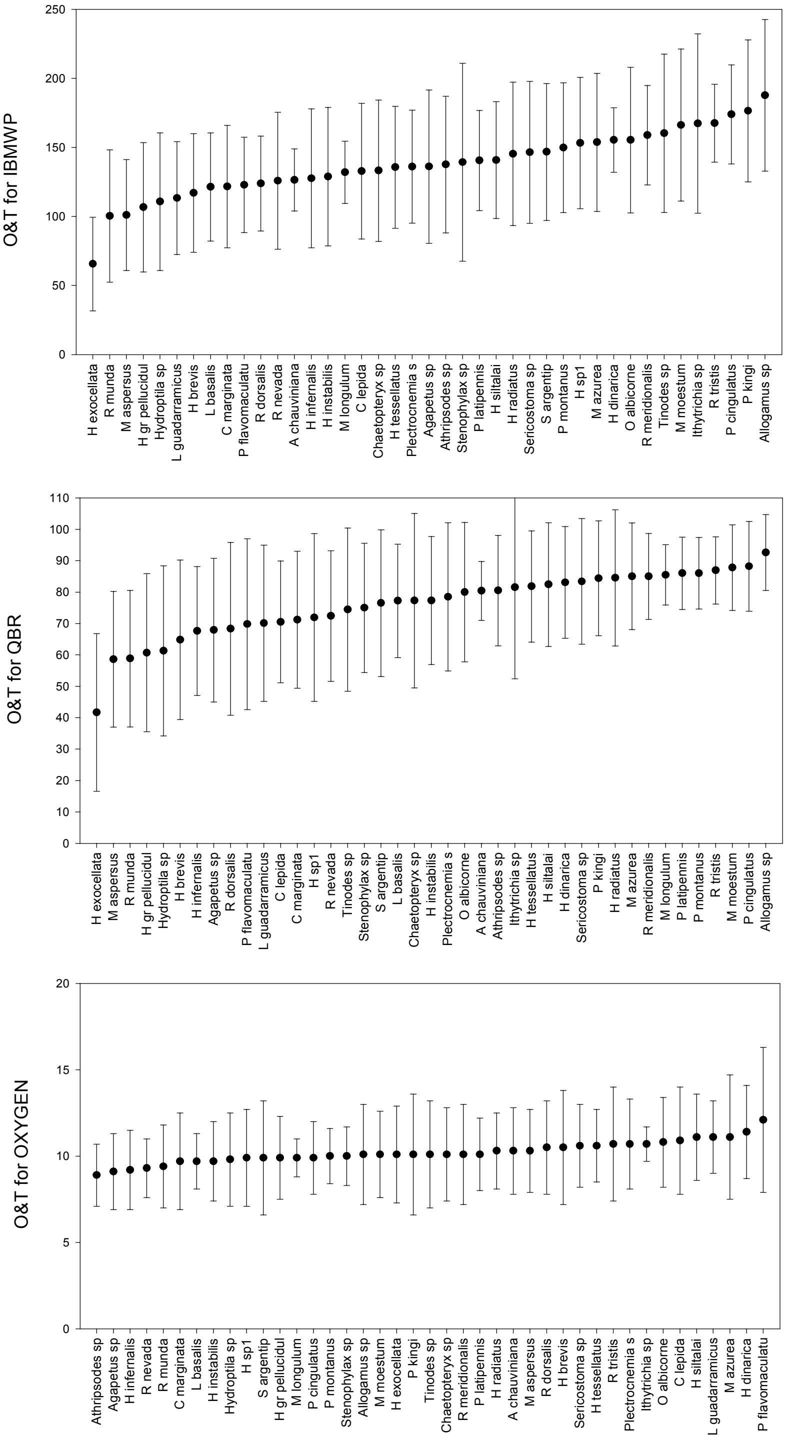


Figure 3. Scatter plots of optimums with error bars indicating the standard deviation (equivalent to tolerance) (O&T) of caddisfly genus/species and IBMWP, QBR and oxygen. X axes are arranged according to increasing optimum. Codes are in Annex 1.

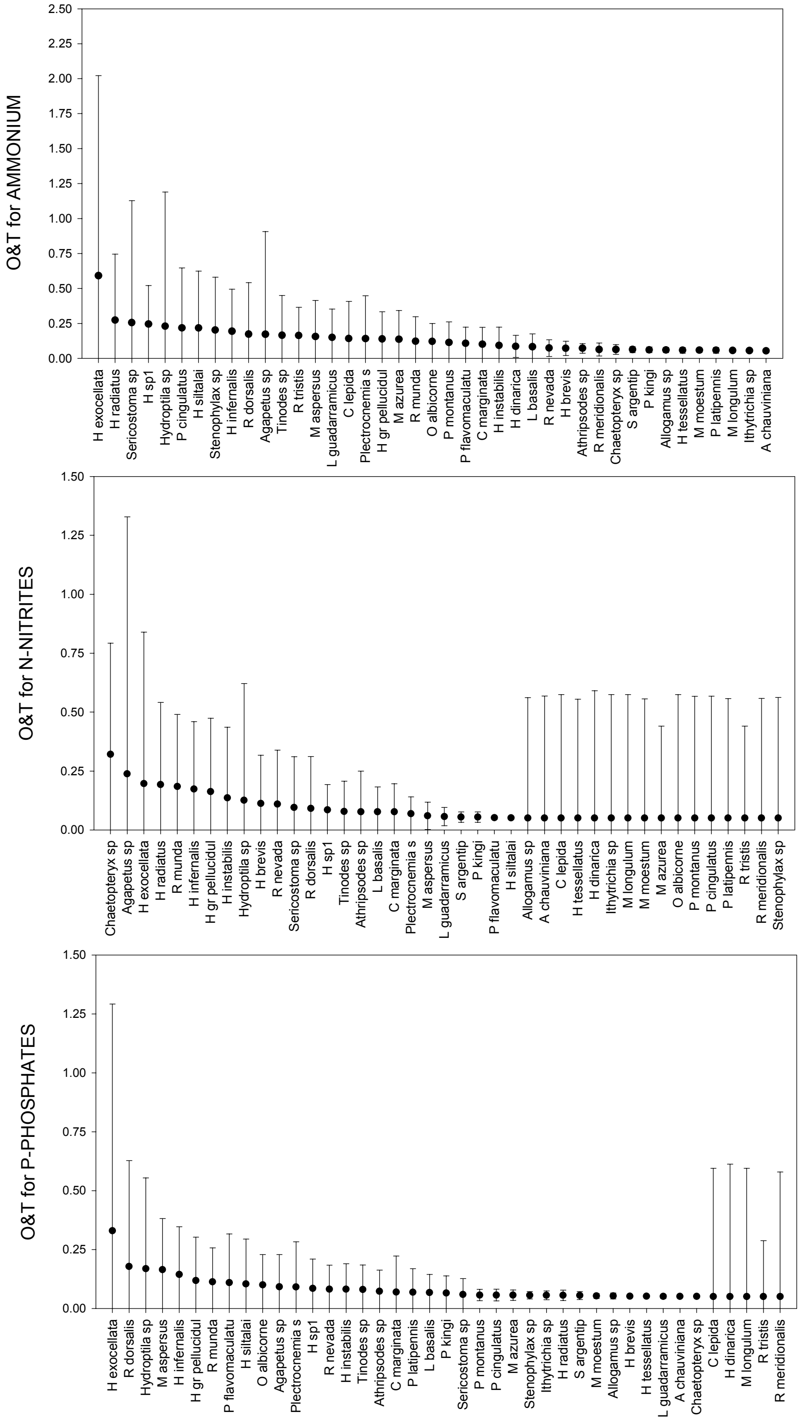


Figure 4. Scatter plots of optimums with error bars indicating the standard deviation (equivalent to tolerance) (O&T) of caddisfly genus/species and ammonium, N-nitrites and P-phosphates. X axes are arranged according to decreasing optimum. Codes are in Annex 1.

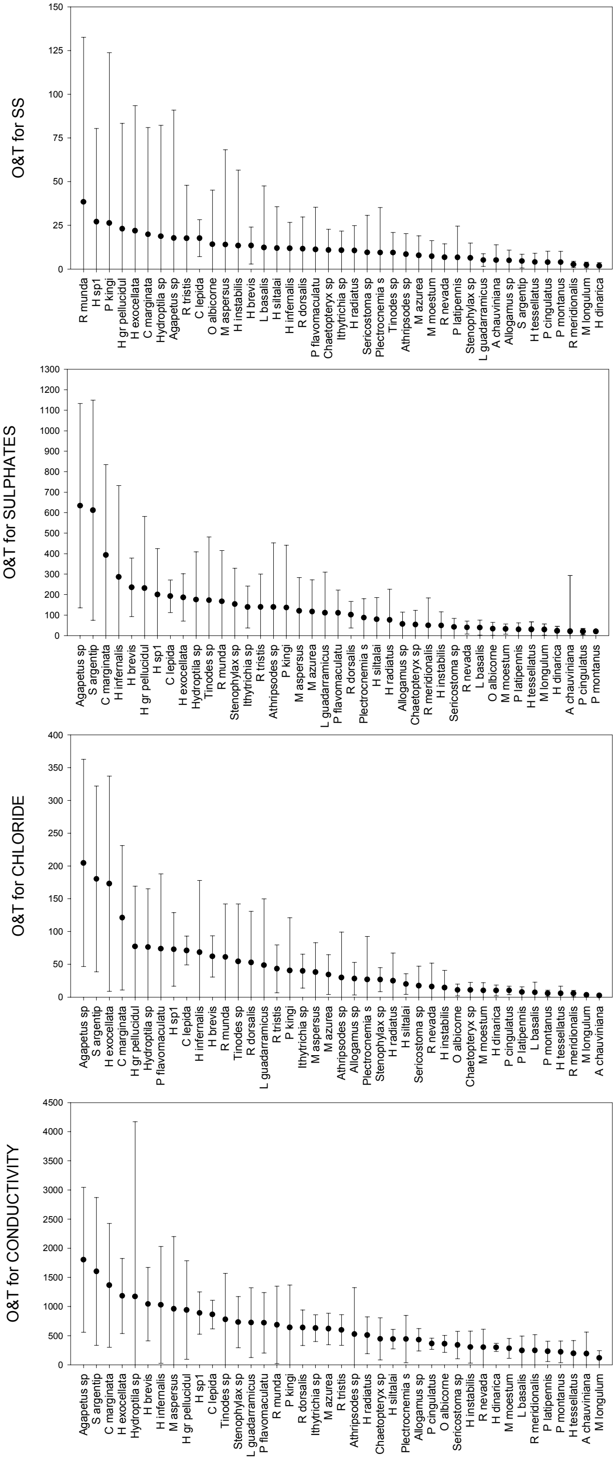


Figure 5. Scatter plots of optimums with error bars indicating the standard deviation (equivalent to tolerance) (O&T) of caddisfly genus/species and suspended solids, sulphates, chloride and conductivity. X axes are arranged according to decreasing optimum. Codes are in Annex 1.

Brachycentridae, Lepidostomatidae, Odontoceridae and Sericostomatidae are the families more sensitive to pollution, with DIS from 4.47 to 5.07 (Figure 7, Table 2). Brachycentridae does not tolerate any of the chemical parameters measured although it can be present in a wide range of oxygen concentration. Lepidostomatidae, Sericostomatidae and Odontoceridae can tolerate minor values of ammonium, P-phosphates and suspended solids. Leptoceridae can tolerate high sulphates and chloride concentrations and even low ammonium, but not other chemical parameters. Instead, Limnephilidae, Psychomyiidae and Rhyacophilidae appear as quite tolerant families for all variables, but more sensitive to salinity by sulphates or chloride. Philopotamidae is able to tolerate high concentration of suspended solids and sulphates but it is very sensitive to eutrophy and toxicity. The most tolerant families are Glossosomatidae, Hydropsychidae and Hydroptilidae, and, with DIS values from 1.61 to 2.14 (Table 2). Glossosomatidae can be present in almost all environmental conditions except to very high P-phosphates concentrations, whereas Hydropsychidae cannot tolerate a very high sulphates or suspended solids. Hydroptilidae present a similar profile with Hydropsychidae. When DIS for families is compared with IBMWP score, a positive relationship is observed between both indexes with some exceptions. Glossosomatidae appears more tolerant to environmental variables than should be expected from a score of 8, and Limnephilidae is slightly more sensitive than Leptoceridae but have a lower IBMWP score.

Figures 8, 9 and 10 present the ecological profiles for caddisfly genus/species. High variability in tolerances is showed by Hydropsychidae species. *Hydropsyche exocellata* is the most tolerant species although quite sensitive to sulphates but very tolerant to chloride. Profiles for *H.* gr. *pellucidula* and *H. sp1* display similar patterns beeing sensitive to P-phosphates and ammonium but tolerant to suspended solids. Contrarily, *H. infernalis* prefers higher sulphates but lower solids, and *C. lepida* prefer low concentrations of solids and sulphates but can be present in a wide range of P-phosphates concentration. The rest of hydropsychids appear to be highly sensitive to environmental variables, with *H. dinarica* beeing very restricted to low sulphates, chloride and solids but tolerating some eutrophy, in contrast to *H. brevis*. Looking at Philopotamidae and Hydroptilidae, *C. marginata* and *Hydroptila* sp. may survive in a wider range of environmental variables while *P. montanus* and *Ithytrichia* sp. are more restricted to clean waters. As we have been seen in previous figures, *Agapetus* sp. appears to be very tolerant to suspended solids, ammonium, sulphates and chloride, but intolerant to eutrophy. As in Hydropsychidae, Limnephilidae also display a high variability in ecological profiles (Figure 9). The abundant *M. aspersus* is the most tolerant species, beeing able to survive at high solids and relatively high P-phosphates and salinity. On the other hand, *H. tesselatus, Potamophylax* sp., *A. chauviniana*, *Allogamus* sp. and *Chaetopteryx* sp. and are restricted to high water quality.

The two species of *Potamophylax* have similar pattern, but *P. cingulatus* appear slightly more tolerant to ammonium. *Stenophylax* sp. is able to tolerate some ammonium and sulphates concentrations. Except for *Rh. munda*, than is able to survive to higher sulphates, chloride and suspended solids, or *Rh. dorsalis* that tolerates some P-phosphates, ammonium and chloride concentrations, rhyacophilids displays profiles quite sensitive to water quality. Except for *M. azurea* quite sensitive to all chemical parameters, the rest of Leptoceridae appear tolerant to high sulphates and chloride concentrations (Figure 10). Similar pattern is observed with Polycentropodidae, with *P. kingi* more tolerant to sulphates, chloride and solids than other genus and species. Finally, *Micrasema* sp. is a very sensitive genus, beeing *M. longulum* more tolerant to P-phosphates than *M. moestum*.

Overall, *H. tessellatus* is the most sensitive taxon with a DIS of 5.27, whereas *H. exocellata* is the most tolerant species (Table 2). Except for some species, hydropsychids present a low DIS value, what agree with patterns observed at family level. Philopotamidae present a low DIS value although one the analyzed species (*P. montanus*) is very sensitive to pollution (DIS=5.2) whereas the other is not (*C. marginata*). Similar pattern is observed in Hydroptilidae, with *Ithytrichia* sp. presenting a DIS of 4.95 and *Hydroptila* sp. of 2.99, or Rhyacophilidae.

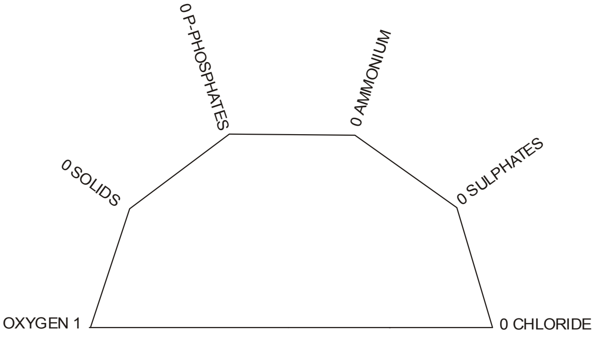
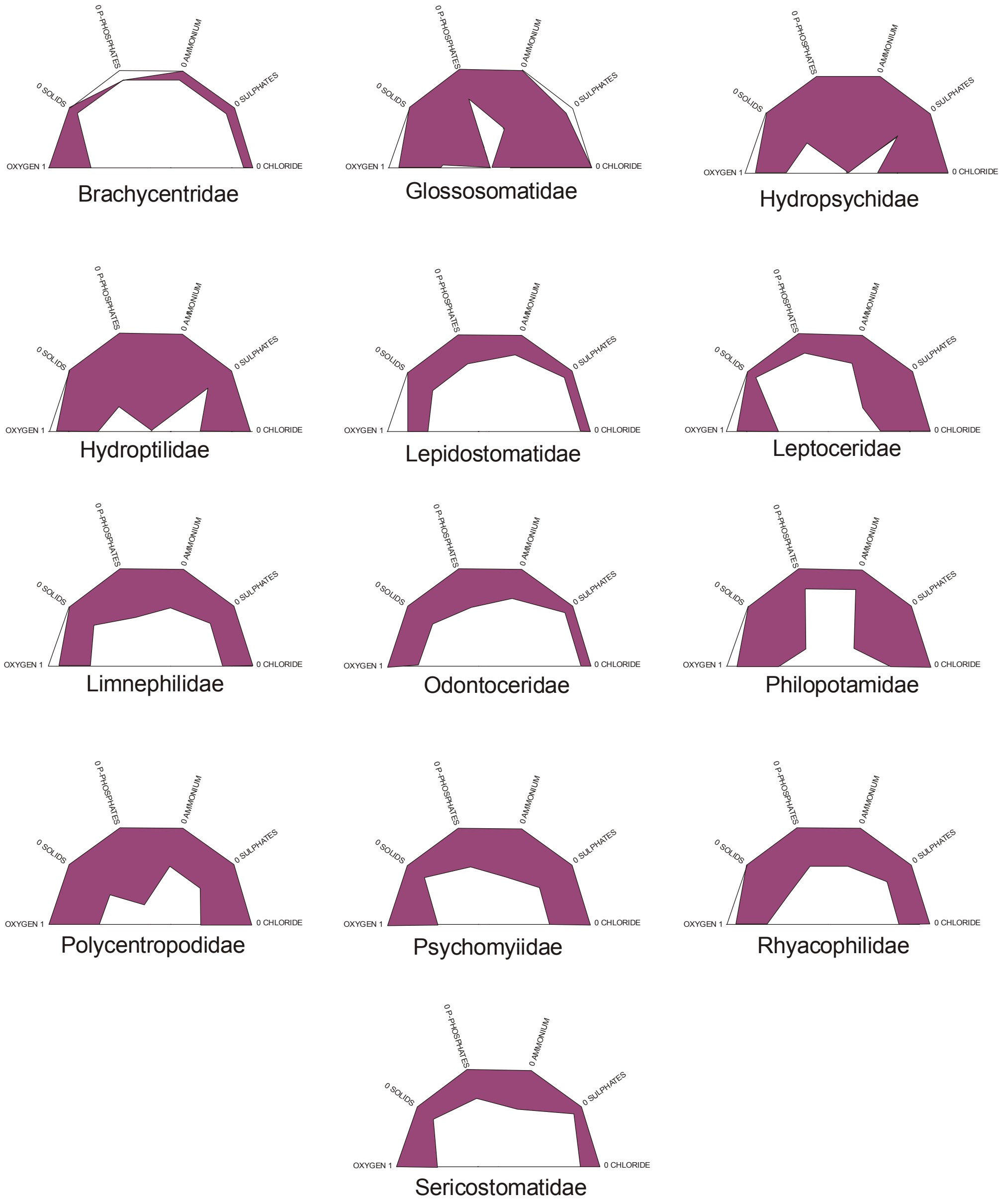


Figure 6. Graph to interpret ecological profiles from Figures 7, 8, 9 and 10.



Brachycentridae

Glossosomatidae

Hydropsychidae

Hydroptilidae

Lepidostomatidae

Leptoceridae

Limnephilidae

Odontoceridae

Philopotamidae

Polycentropodidae

Psychomyiidae

Rhyacophilidae

Sericostomatidae

Figure 7. Ecological profiles for caddisfly families. Only oxygen, suspended solids (solids), P-phosphates, ammonium, sulphates and chloride are plotted.

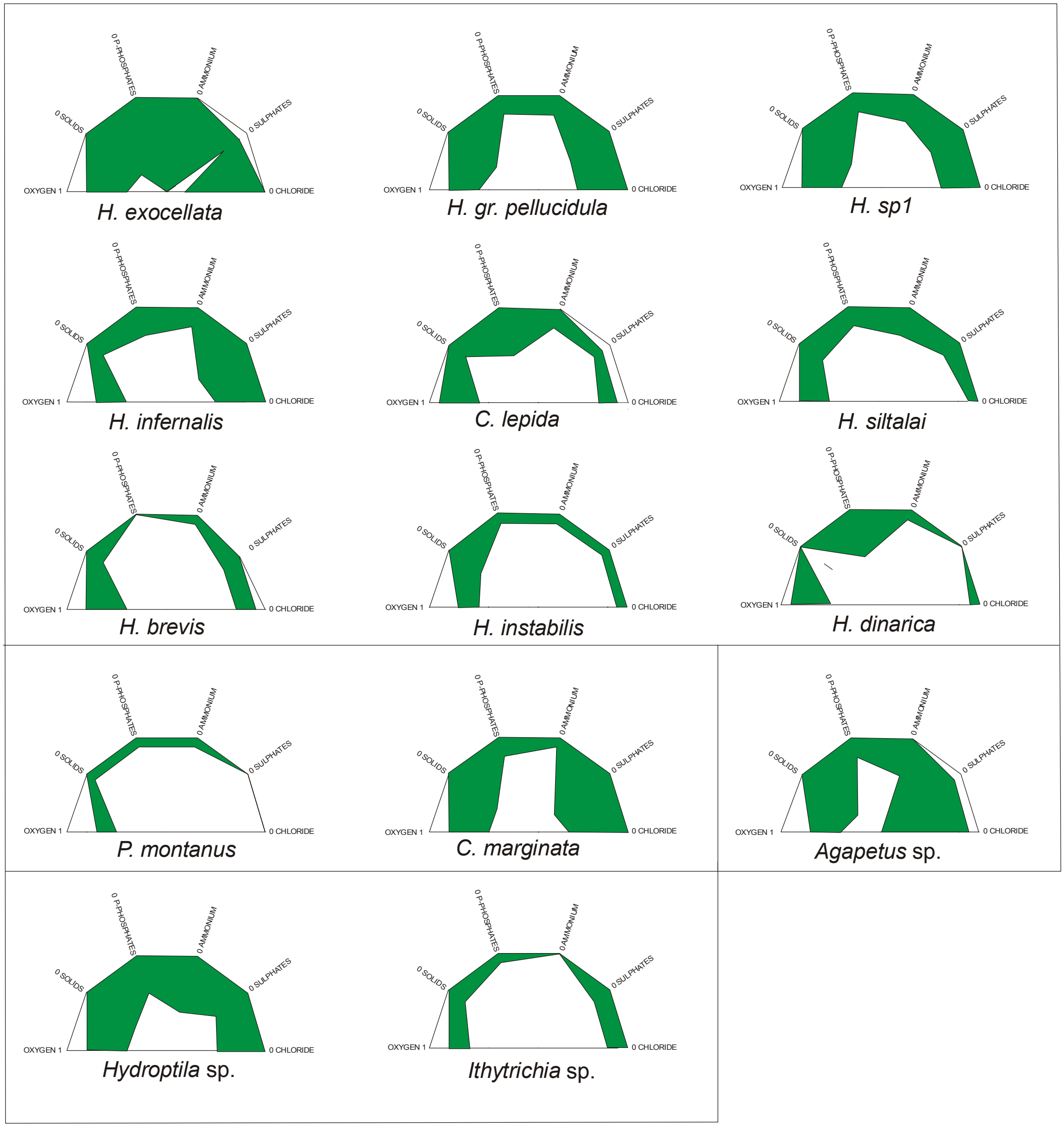
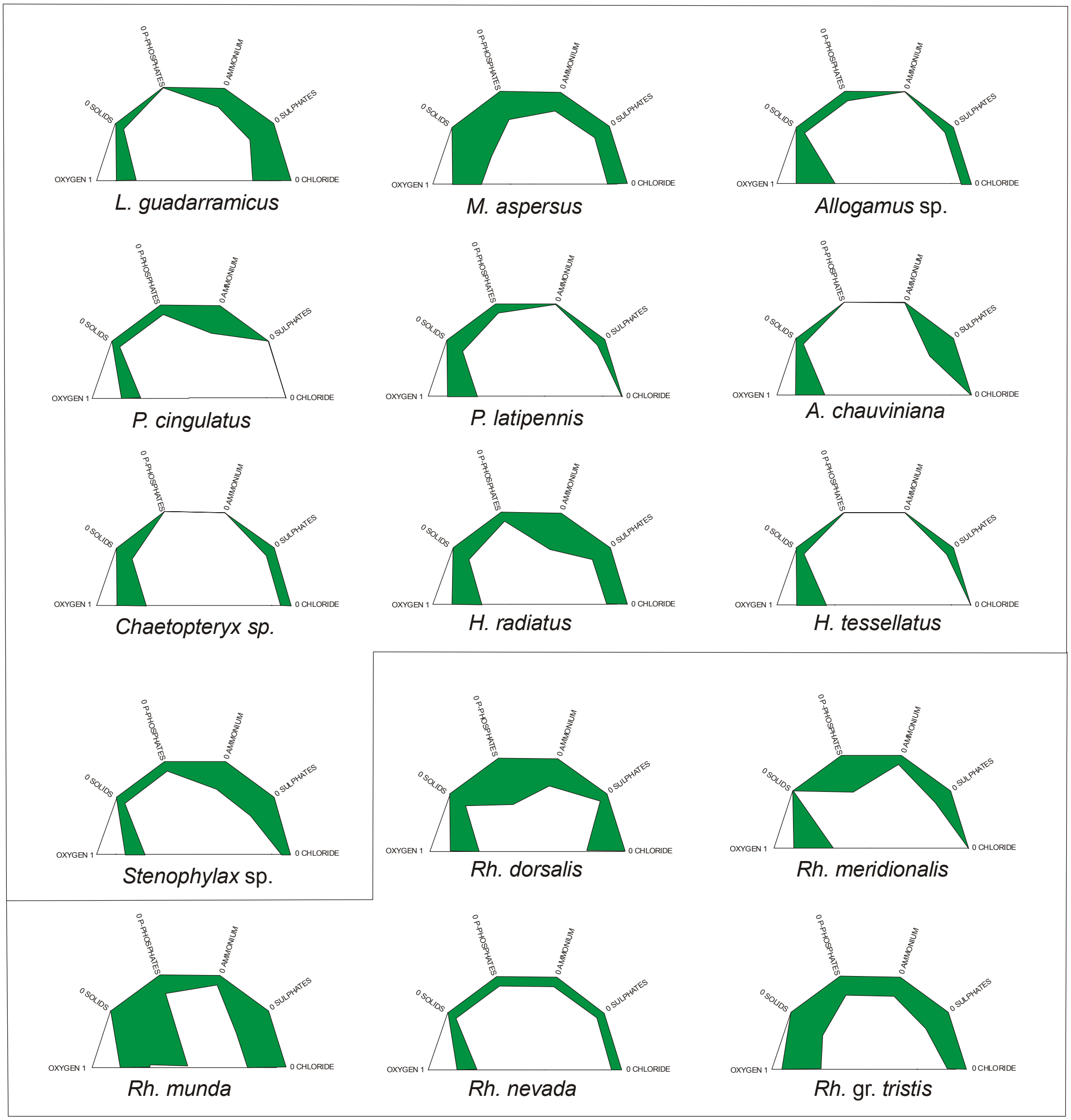


Figure 8. Ecological profiles for caddisfly genus/species grouped by families. Only oxygen, suspended solids (solids), P-phosphates, ammonium, sulphates and chloride are plotted.



L. guadarramicus
M. aspersus
Allogamus sp.
P. cingulatus
P. latipennis
A. chauviniana
Chaetopteryx sp.
H. radiatus
H. tessellatus
Stenophylax sp.
Rh. dorsalis
Rh. meridionalis
Rh. munda
Rh. nevada
Rh. gr. *tristis*

Figure 9. Ecological profiles for caddisfly genus/species grouped by families. Only oxygen, suspended solids (solids), P-phosphates, ammonium, sulphates and chloride are plotted.

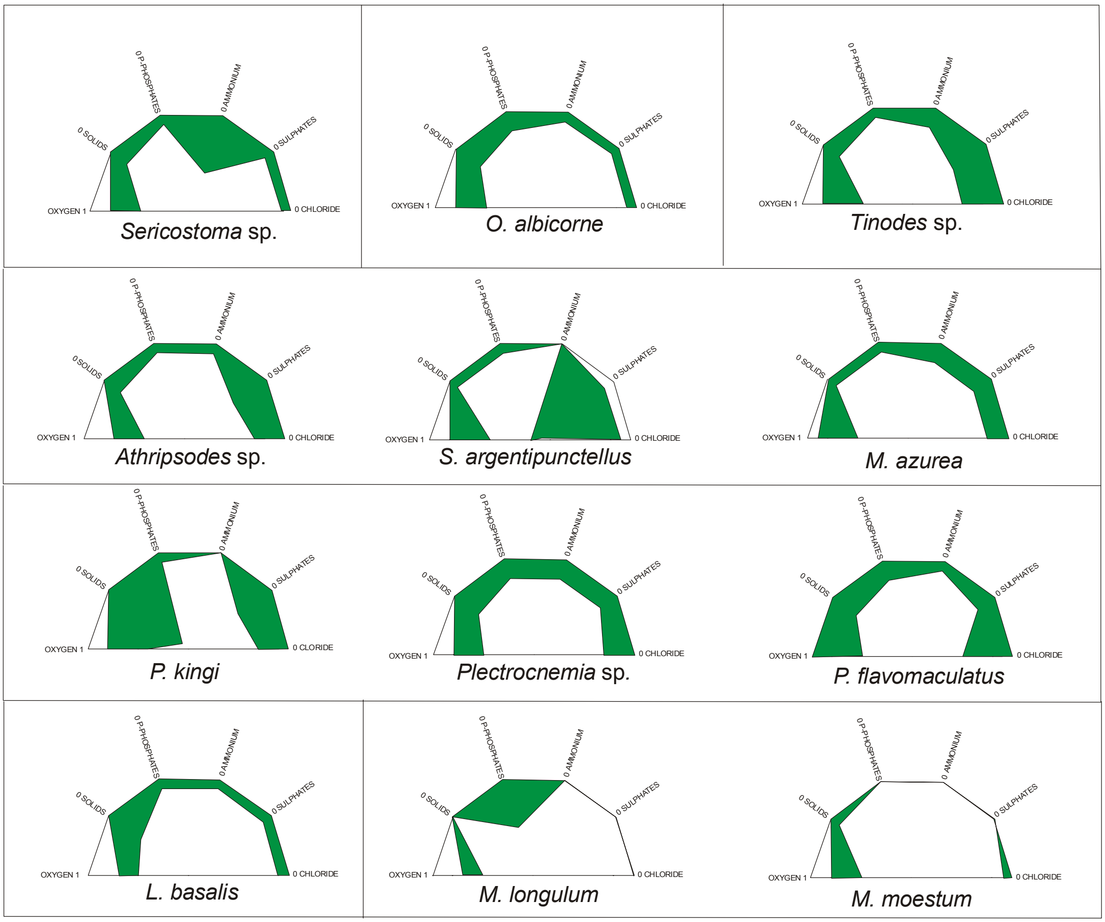


Figure 10. Ecological profiles for caddisfly genus/species grouped by families. Only oxygen, suspended solids (solids), P-phosphates, ammonium, sulphates and chloride are plotted.

Table 2. DIS value from ecological profiles for families and genus/species. Taxa are arranged by decreasing DIS. High DIS indicate a very sensitive taxa whereas low values are typical from the most tolerant caddisfly. The score used in IBMWP is also presented.

	DIS	**IBMWP Score**
Brachycentridae	5.07	10
Lepidostomatidae	4.75	10
Odontoceridae	4.55	10
Sericostomatidae	4.47	10
Limnephilidae	3.92	7
Leptoceridae	3.79	10
Psychomyiidae	3.71	8
Rhyacophilidae	3.65	7
Polycentropodidae	3.04	8
Philopotamidae	2.93	8
Hydroptilidae	2.14	6
Hydropsychidae	1.93	5
Glossosomatidae	1.61	8

	DIS
H. tessellatus	5.27
P. montanus	5.20
M. moestum	5.15
P. latipennis	5.04
A. chauviniana	5.04
Allogamus sp	5.02
Chaetopteryx sp.	5.02
M. longulum	4.96
Ithytrichia sp.	4.95
Rh. nevada	4.95
P. cingulatus	4.95
H. dinarica	4.86
L. basalis	4.81
O. albicorne	4.75
Rh. meridionalis	4.72
M. azurea	4.68
Stenophylax sp.	4.65
L. guadarramicus	4.58
H. brevis	4.57
H. instabilis	4.56
H. radiatus	4.50
H. siltalai	4.47
Athripsodes sp.	4.44
Sericostoma sp.	4.41
Plectrocnemia sp.	4.38
Rh. gr. *tristis*	4.21
P. flavomaculatus	4.15
C. lepida	4.12
Tinodes sp.	4.09
M. aspersus	4.00
Rh. dorsalis	4.00
H. sp1	3.68
P. kingi	3.60
H. infernalis	3.58
H. gr. *pellucidula*	3.46
S. argentipunctellus	3.36
Rh. munda	3.33
C. marginata	3.17
Hydroptila sp.	2.99
Agapetus sp.	2.13
H. exocellata	1.56

DISCUSSION

The wide range of ecological profiles showed by caddisfly families and species in the Mediterranean area confirm the idea expressed by several authors that Trichoptera is an ideal group to assess water quality (e.g., Resh, 1992; Berlin & Thiele, 2002; Waringer & Graf, 2002; Dohet, 2002). In this study, a gradient of caddisfly families and species have been provided using several chemical and other ecosystem properties as riparian vegetation and the macroinvertebrate community. Consequently, caddisflies appear to be good indicators of water quality, and a good tool to protect aquatic ecosystems where they exist, especially for the most sensitive species (de Moor, 1999). However, some overlooked variables because unavailable, would refine final ecological profiles and tolerances to water quality variables. For example, heavy metals (Besch *et al.*, 1979; Darlington *et al.*, 1987), hydrocarbons (Simpson, 1980) or pesticides (Décamps *et al.*, 1973) have been proved to have a significant effect on caddisflies taxa. Several mechanisms have been identified as the responsible to allow the presence of some species in poor water conditions and avoid others (see Wiederholm, 1984): morphological adaptations, behavior, metabolic processes, osmoregulation, or detoxification.

In general, our results agree with the ones obtained from ecological studies in literature. Looking at the ecological profiles of several species of *Rhyacophila* sp., Moretti & Mearelli (1981) found that *Rh. dorsalis* had a wider ecological profile than *Rh.* gr. *tristis*, what can be also observed in our results. *Rh. dorsalis* has been found in headwater and midstream rivers with different biological quality (Bonada *et al.*, Chapter 8). Species with a quite restricted ecological profile as *H. siltalai*, *M. azurea* or *O. albicorne* were proved to be species with high indicator values of sites with low organic pollution (Dohet *et al.*, 2002). However, our study suggests that some caddisflies families and species in the Iberian rivers are sensitive to some variables but more tolerant to others, indicating a higher ecological diversification in the sampled mediterranean rivers. This phenomena is rarely noticed in literature because most of the studies have been performed using few species or with species from a single family. Moreover, most of the published studies looking at the effects of specific chemical parameters in caddisflies in behaviour, life history or metabolic processes only include one or two chemical variables (see Resh, 1992). Both aspects make difficult interpretations of results obtained using numerous chemical variables (Stuijfzand, 1999), as in the present study.

Overall, except for some species, caddisflies can be present in a wide range of riparian and biological conditions. Riparian vegetation is an important element to the macroinvertebrate community organization (e.g., Molles, 1982; Aguiar *et al.*, 2002) that indirectly may affect caddisfly composition (Molles, 1982; Bonada *et al.*, Chapter 7). Similarly, biological adjacent community can be more or less divers because water quality characteristics, by substrate availability or temporality (Bonada *et al.*, Chapter 5). Thereby, caddisfly composition is indirectly affected by both factors but directly exposed to chemical features. For example, different species of the net-spinning Hydropsychidae are segregated to different suspended solids concentrations probably because their feeding and net morphological requirements (e.g., Gordon & Wallace, 1975; Wiggins & Mackay, 1978; Alstad, 1987). Hydropsychidae have been found as a very tolerant family over the world (e.g., Mackay, 1979; Vuori, 1995) with some species able to tolerate anaerobic conditions during several hours (Becker, 1987). Hydropsychid species appear segregated at different water qualities along the river (Décamps *et al.*, 1973; Gordon & Wallace, 1975; Ross & Wallace, 1982; Gallardo-Mayenco *et al.*, 1998), with *H. exocellata* considered a very tolerant species by several authors (e.g., Higler & Tolkamp, 1983; Gallardo-Mayenco *et al.*, 1998; Usseglio-Polatera & Bournaud, 1989). Although in our results this is true for species, at family level Glossosomatidae is more tolerant than Hydropsychidae, especially to salinity.

Numerous controversies are found in literature about the appropriate taxonomical level to be used in water monitoring, especially to know if environmental requirements for lower taxonomical levels may be extrapolated to family or orders (Resh & Unzicker, 1975; Cranston, 1990; Lenat & Resh, 2001). According to our results, similar ecological profiles are shown by all taxonomical levels when a family has few species (e.g., Odontoceridae) or when family displays a restricted profile (e.g., Brachycentridae, Lepidostomatidae). In other cases, as in the abundant Hydropsychidae or Hydroptilidae, ecological patterns from family level are very different from the ones obtained from some species. Resh & Unzicker (1975) looking at tolerances of *Ceraclea* sp. (*Athripsodes* sp.) observed different pollution tolerances at genus and species level, what would agree with some of our results. Therefore, the use of family level might underestimate higher water qualities, specially in that situation when habitat structure or temporality yield a poor macroinvertebrate diversity (e.g., Bonada *et al.*, Chapter 5), because scores at family level usually use intermediate species tolerance values (Lenat & Resh, 2001). In the same sense, in a very poor water quality conditions, indexes at family levels may overestimate water quality more than those based in species. Biological indexes at species level have been used in some countries (e.g., the saprobic system in Austria) providing good results (Moog & Chovarec, 2000). In that sense, because the DIS values obtained here are a representation of the sensitivity (or tolerance) of taxa, it could be used to obtain a biological index using caddisflies at genus/species level, similarly, for example, to the saprobic method used in Austria. However, caddisfly larvae identification is not easy especially in areas where larvae are poorly known as in the Iberian Peninsula (see Vieira-Lanero, 2000; Bonada *et al.*, Chapter 6). Though some error is incorporated, indexes at family level although may be more adequate in terms of cost-efficiency, especially when few taxonomic experts are available (Lenat & Resh, 2001).

The biological index IBMWP has been extensively applied in the Iberian Peninsula beeing highly sensitive to water quality (Camargo, 1993; Zamora-Muñoz *et al.*, 1995; Alba-Tercedor, 1996; Zamora-Muñoz & Alba-Tercedor, 1996; García-Criado *et al.*, 1999; Prat *et al.*, 1999, 2001; Alba-Tercedor & Pujante, 2000). Overall, scores assigned to caddisflies families in the IBMWP agree with the tolerance to pollution for each family in the mediterranean sampled area, and only in some cases minor modifications may be applied, especially in Glossosomatidae. For this last family, and especially in *Agapetus* genus, some larvae were found very abundant in semiarid areas with lower water qualities than should be expected from a score of 8 in the IBMWP. Although conductivity (mainly by sulphates) present in that areas may have a geological origin (see Toro *et al.*, in press), larvae appear tolerant to some ammonium and chloride concentrations, what might suggest a reassignment of its IBMWP score. These divergences observed in Glossosomatidae between its DIS and IBMWP scores may be related to the specific sensitivities displayed by several species present in some areas but absent in others. In that sense, for example *A. fuscipes* has been considered as a very sensitive species (González del Tánago & García de Jalón, 1984; Wallace *et al.*, 1990), whereas *A. incertulus* have been found in slightly polluted streams with high salinity (see Bonada *et al.*, Chapter 6).

Ecological profiles are dynamic structures that can change in space and time, and therefore, studies performed in small areas or integrating short periods may be incomplete (Moretti & Mearelli, 1981). Moreover, environmental variables may also change widely in time and space what difficult the establishment of organisms tolerances to pollution (Resh & Unzicker, 1975). Consequently, when ecological profiles are obtained from field data instead of experimental studies, large sets of data integrated in time and space are required to determine species' autoecology with certainty. However, several considerations have to be done when optimum and tolerances are calculated assuming a unimodal distribution of organisms. In some cases, it has been demonstrated that organisms can fit a bimodal, multimodal or skewed distribution (Hengeveld, 1990). Several factors have been considered as the responsible to that deviation as biotic interactions (Westman, 1991), life cycle stage (Verdonschot & Higler, 1992), or because the environmental variable does not show a gradient (Wiens, 1989). However, in most of the cases and maybe because incomplete data, is not possible to know if organisms display an unimodal distribution with certainty (Verdonschot & Higler, 1992), and these considerations must be assumed and results interpreted with caution.

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Annex 1. List of caddisfly families and genus/family used in the analysis with the number of records (N).

Family	**N**	***Genus/Species***	**N**	**Code**
Brachycentridae	37	*Micrasema longulum*	10	M longulum
		Micrasema moestum	23	M moestum
Glossosomatidae	61	*Agapetus* sp.	38	Agapetus sp
Hydropsychidae	449	*Cheumatopsyche lepida*	10	C lepida
		Hydropsyche brevis	23	H brevis
		Hydropsyche dinarica	10	H dinarica
		Hydropsyche exocellata	136	H exocellata
		Hydropsyche gr. *pellucidula*	159	H gr pellucidul
		Hydropsyche infernalis	31	H infernalis
		Hydropsyche instabilis	115	H instabilis
		Hydropsyche siltalai	30	H siltalai
		Hydropsyche sp1	13	H sp1
Hydroptilidae	254	*Hydroptila* sp.	222	Hydroptila sp
		Ithytrichia sp.	10	Ithytrichia sp
Lepidostomatidae	62	*Lasiocephala basalis*	59	L basalis
Leptoceridae	95	*Athripsodes* sp.	38	Athripsodes sp
		Mystacides azurea	21	M azurea
		Setodes argentipunctellus	21	S argentip
Limnephilidae	222	*Allogamus* sp.	15	Allogamus sp
		Anomalopterygella chauviniana	12	A chauviniana
		Chaetopteryx sp.	11	Chaetopteryx sp
		Halesus radiatus	18	H radiatus
		Halesus tessellatus	30	H tessellatus
		Limnephilus guadarramicus	29	L guadarramicus
		Mesophylax aspersus	60	M aspersus
		Potamophylax cingulatus	13	P cingulatus
		Potamophylax latipennis	29	P latipennis
		Stenophylax sp.	13	Stenophylax sp
Odontoceridae	12	*Odontocerum albicorne*	10	O albicorne
Philopotamidae	83	*Chimarra marginata*	55	C marginata
		Philopotamus montanus	14	P montanus
Polycentropodidae	139	*Plectrocnemia* sp.	23	Plectrocnemia s
		Polycentropus kingi	27	P kingi
		Polycentropus flavomaculatus	19	P flavomaculatu
Psychomyiidae	64	*Tinodes* sp.	44	Tinodes sp
Rhyacophilidae	224	*Rhyacophila* gr. *tristis*	13	R tristis
		Rhyacophila dorsalis	35	R dorsalis
		Rhyacophila meridionalis	23	R meridionalis
		Rhyacophila munda	63	R munda
		Rhyacophila nevada	61	R nevada
Sericostomatidae	74	*Sericostoma* sp.	61	Sericostoma sp

Annex 2. Chemical ranges from several variables from Prat *et al.* (2001).

IBMWP	
<15	Extremely poor community
16-35	Very polluted waters
36-60	Polluted waters
61-100	Moderately polluted waters
>100	Very good water quality

QBR	
?25	Extreme dregadation, very poor quality
30-50	Strong alteration, poor quality
55-70	Considerable disturbance, fair quality
75-90	Some disturbance, good quality
?95	Riparian habitat in natural condition

AMMONIUM	(mg/l)
<0.1	Clean waters, without stress
0.1-0.4	Waters with some stress depending on the pH
0.5-0.9	Fair water quality
1-4	Poor water quality
>4	Very poor water quality, with high toxicity

N-NITRITES (mg/l)	
<0.03	Clean waters, without stress
0.03-0.3	Fair water quality
>0.3	Very Poor water quality, with high toxicity

P-PHOSPHATES (mg/l)	
<0.03	Clean waters, without stress and eutrophy
0.03-0.09	Waters with some eutrophy
0.1-0.29	Fair water quality and eutrophy
0.3-0.5	Poor water quality and high eutrophy
>0.5	Very poor water quality and very high eutrophy

SULPHATES (mg/l)	
<250	Clean waters, without stress
250-1000	Fair water quality by pollution of gypsum basin geology
>1000	Very Poor water quality

CHLORIDE (mg/l)	
<25	Clean waters, without stress
25-99	Waters with some stress
100-199	Fair water quality
200-1000	Poor water quality
>1000	Very poor water quality, saline

Chapter 9

RELATIONSHIP BETWEEN POLLUTION AND FLUCTUATING ASYMMETRY IN A POLLUTION-TOLERANT CADDISFLY *Hydropsyche exocellata* (TRICHOPTERA, INSECTA).

INTRODUCTION

Aquatic macroinvertebrates have been widely used as indicators of pollution in rivers and streams (e.g., Hynes, 1960; Reynoldson, 1984; Cairns & Pratt, 1993), and are part of most of protocols to assess water quality over the world. Because their sensitivity to pollution, caddisfly have been used in many cases to assess water quality (Malicky, 1981; Usseglio-Polatera & Bournaud, 1989; Resh, 1992; de Moor, 1999; Stuijfzand *et al.*, 1999; Bonada *et al.*, Chapter 8) at different taxonomical levels and looking at different responses. Thus, they have been used at order level in some multimetric approaches (e.g., EPT index — Barbour *et al.*, 1999) or included in some biological indexes at family or even species level (see Resh, 1992). Less frequent, although increasing, are the studies performed at individual level. In that sense it is interesting to point out the works using deformities (e.g., Décamps *et al.*, 1973; Petersen & Petersen, 1983; Camargo, 1991; Vuori, 1995; Vuori & Kukkonen, 2002), changes in colour patterns (Chapely et al., 1997), morphological asymmetries (e.g., Clarke, 1993; Hogg et al., 2001; Bonada & Williams, 2002) or toxicity tests (e.g., Greve *et al.*, 1998). Because biological indexes only confer information about the presence or absence of taxa in a site, without including the condition of the population of those taxa, biomarkers give us extra information about the effect of environmental pollutants to organisms (Peakall & Walker, 1994). In that sense, it has been considered that these studies may be useful in conservation ecology because knowing the population status of one species in front a pollutant may be a tool to avoid their disappearance if disturbance increases (Clarke, 1995).

Clarke (1993) pointed out the need to assess water quality using techniques focused in developmental processes at individual level. It is widely accepted that developmental stability of individuals (i.e., the ability to develop properly in the face of genetic and environmental stresses that tend to upset development —*sensu* Watson & Thornhill, 1994) may be affected by genetic or environmental factors (e.g., Van Valen, 1962; Clarke, 1992; Palmer & Strobeck, 1992). Developmental stability has been widely measured using Fluctuating asymmetry (FA) (i.e., random and small deviations from perfect bilateral symmetry in morphological traits) (e.g., Clarke, 1992). Thus, if high environmental stress yields a low developmental stability, this is measured as a high level of fluctuating asymmetry. Consequently, FA may be used as a cost-effective measure of environmental stress (e.g., Leary & Allendorf, 1989; Drover et al., 1999; Cuervo, 2000; Hogg et al., 2001). Recent studies conclude that Antisymmetry (AA) and in some cases Directional asymmetry (DA) can be also a measure of development stress (Graham *et al.*, 1993; Kark, 2001).

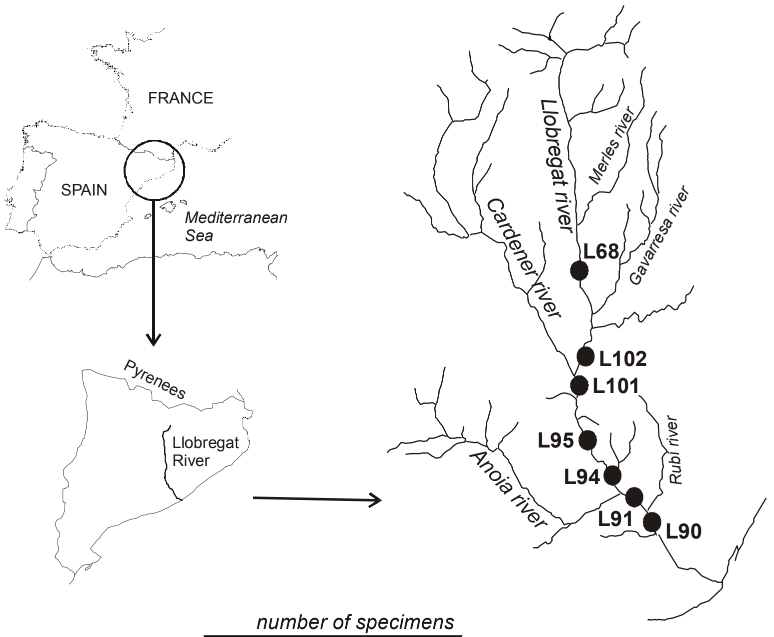
The three asymmetries (FA, AA, and DA) affecting organisms may be distinguished looking at the distribution frequencies of the measured values of a morphological trait comparing right and left side (R_i-L_i) (e.g., Van Valen, 1962; Parsons, 1990; Palmer & Strobeck, 1986). Directional Asymmetry (DA) is present in morphological character when the differences between the right and the left sides of the body (R-L differences) are normally distributed with a mean significantly different from zero. Antisymmetry (AA) occurs when the R-L differences are platykurtic or bimodal distributed, with a mean about zero. And finally, fluctuating Asymmetry (FA) is demonstrated when the R-L differences are normally distributed with a mean of zero in the ideal case (Van Valen, 1962; Palmer, 1994) although some leptokurtic distributions can be also admitted (see Palmer & Strobeck, 1992).

Studies relating FA with changes in the environment has increased in the last decade in many areas in Ecology (see review in Hogg et al., 2001). Some of the studies performed have been focused in aquatic macroinvertebrates relating FA with water quality variables (e.g., Groenendijk *et al.*, 1998; Dobrin & Corkum, 1999; Drover et al., 1999; Hardersen *et al.*, 1999; Hogg et al., 2001; Servia, 2001) or biological interactions (e.g., the effect of larval density in *Culex* sp. by Mpho et al., 2000 or the effect of a parasite in *Gammarus pulex* by Alibert et al., 2002). Most of these studies have been performed using midges (e.g., Clarke et al., 1995; Groenendijk *et al.*, 1998; Servia, 2001), Ephemeroptera (Dobrin & Corkum, 1999), Plecoptera (Hogg et al., 2001; Heteroptera (Drover et al., 1999); Crustacea (Savage & Hogarth, 1999; Alibert et al., 2002), or Odonata (Hardersen et al., 1999; Hardersen & Frampton, 1999; Hardersen, 2000) Overall, significant relationships between pollution variables and FA are reported, although it has been noticed that negative results in FA are rarely published (Dobrin & Corkum, 1999). However, although knowing its adequacy in water quality studies, few works have been performed looking at the asymmetries in caddisflies (but see Bonada & Williams, 2002). The present study try (1) to determine if levels of fluctuating asymmetry in the tolerant caddisfly *Hydropsyche exocellata* increase downstream a river system as a consequence of pollution using a large set of morphological traits and (2) to indicate possible chemical factors implied.

METHODOLOGY

Sampling area

The Llobregat basin with a drainage basin of 4948 km^2 is located in the northeast Spain (Figure 1). The main channel (the Llobregat River) flows from 1360 m to the sea in 145 km. The area is subjected to a mediterranean climate with an annual mean precipitation between 950 mm in headwaters to 550 mm in lowland reaches (Prat *et al.*, 1984; González *et al.*, 1985). It presents a dominant calcareous geology although some sedimentary deposits are found near the mouth (see Robles *et al.*, in press). Except for riparian zones and some isolated areas, sclerophyllous and evergreen trees and shrubs mainly compose basin vegetation. As in other mediterranean basins, the Llobregat has been largely affected by human activities as agriculture, cattle, urbanization, salinization by mining activity, water abstraction and regulation... affecting drastically the ecological status of the main river and tributaries (Prat *et al.*, 1984; 1997; 1999; 2000; 2001; 2002; González *et al.*, 1985). The first chemical and biological quality studies performed in the Llobregat basins date back from the late 70's (Prat *et al.*, 1984). During the 90's the construction of several water treatment plants along the Llobregat river and tributaries and a salt-collector improved substantially the chemical and biological water quality, allowing the survival of several macroinvertebrates in the lowland reaches (Prat *et al.*, 1997; 1999; 2000; 2001; 2002).



		number of specimens
US	L68	9
	L102	25
MS	L101	12
	L95	30
	L94	30
DS	L91	30
	L90	29

Figure 1. Sampling area. The location of sampling sites in Llobregat River, and the number of specimens measured for sites are presented. Groups of sites used to compare levels of asymmetry and pollution are also presented (Upstream sites: US; Midstream sites: MS; Downstream sites: DS).

Sampling sites and procedure

Several reasons make *Hydropsyche exocellata* an ideal species to test the effect of pollution on the fluctuating asymmetry of larvae. *H. exocellata* has been considered as a pollution-tolerant species by several authors (e.g., Higler & Tolkamp, 1983; González del Tánago & García de Jalón, 1984; González *et al.*, 1985; Gallardo, 1994; Gallardo-Mayenco *et al.*, 1998; Usseglio-Polatera & Bournaud, 1989; Bonada *et al.*, Chapter 8), and when it is present it has been found with high abundances (Soler & Puig, 1999). It presents a variable life cycle from two to several generations per year (e.g., Tachet & Bournaud, 1981; García de Jalón, 1986; Soler & Puig, 1999) ant therefore specimens from the last instar can be found along the year (Soler & Puig, 1999; Vieira-Lanero, 2000).

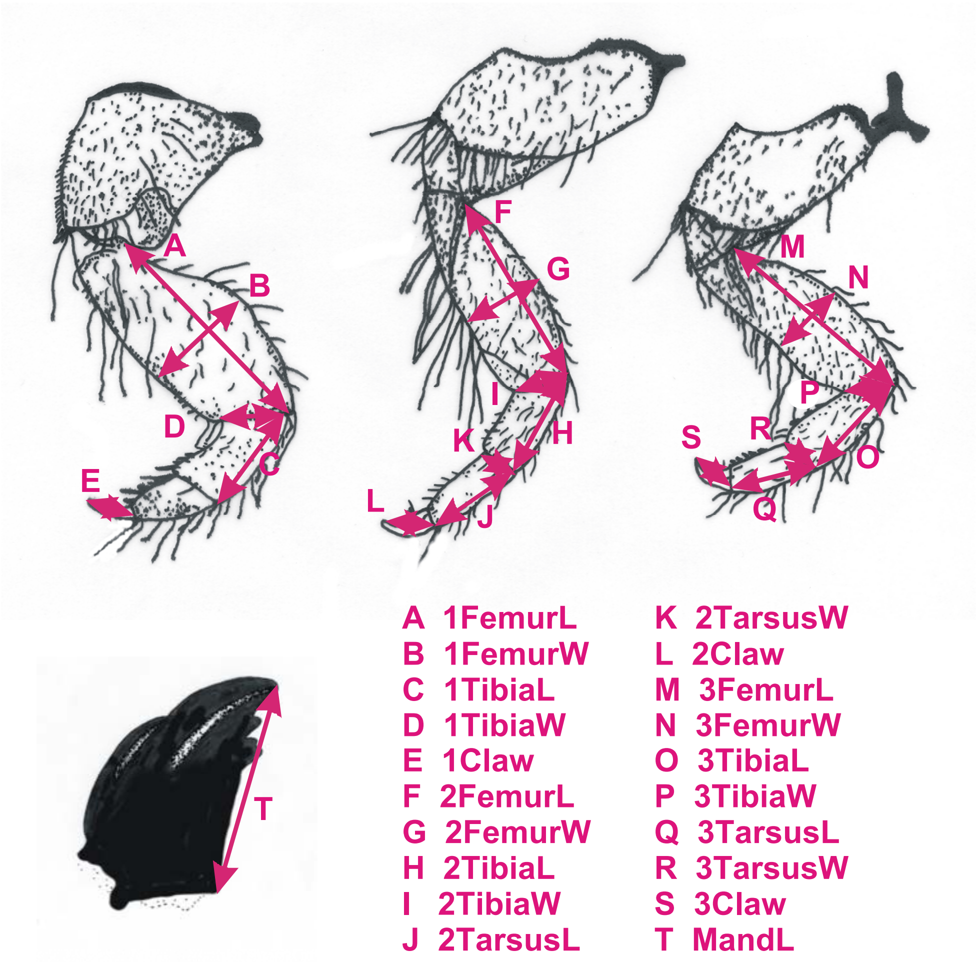


Figure 2. Measured traits on the first, second and third leg, respectively from left to right, and the mandible.

Larvae of *H. exocellata* were obtained from 7 sites in Llobregat River in summer 2000 (Figure 1). These localities have been grouped in three groups to facilitate comparisons and to increase sample size, differing in chemical and biological variables: upstream sites, midstream sites, downstream sites. These groups have been defined according to the limit of distribution of *H. exocellata* in Llobregat River. The upper localities (US: L68 and L102) present a better chemical and biological quality compared with downstream reaches, although L102 is slightly affected by salinity than L68 (Prat *et al.*, 1997; 1999; 2000; 2001; 2002). Before midstream sites (MS; L101, L95, L94), the Llobregat river receives the Cardener, which is highly influenced by salinity because the presence of several salt deposits and mining activities (Prat *et al.*, 1984), affecting notoriously the water quality of Llobregat river. In the lower parts (DS: L91, L90), Llobregat River is influenced by Anoia and Rubí rivers carrying out a high organic and industrial pollution despite the recent improvement on water quality (Prat *et al.*, 2002). Chemical data from spring and summer was obtained from Prat *et al.* (2002).

Larvae were collected in the field during summer. Ideally, 30 last instar individuals (1.250-1.950 mm head width, Soler & Puig, 2000) were analyzed for each sampling site (see data in Figure 1), although because of low population abundances this number was lower in some localities. A total of 20 bilateral morphological traits were selected to test the presence of FA and to relate it with pollution variables (Figure 2). Pair legs and mandibles were dissected in a slide with glycerin to facilitate the proper orientation of each piece to be measured. Left and right pieces from each trait were measured separately, under a stereoscope provided with a micrometer with an accuracy of 0.019 mm at the maximum magnification possible. Missing or damaged pieces (e.g., claws of entire legs) were not measured. Because FA might be highly biased by measurement error (e.g., Palmer, 1994; Merilä & Bjorklund, 1995; Björklund & Merilä, 1997), a subsample of 30 individuals selected at random was measured twice one day apart. Measurement error for each trait was detected with a two-way mixed-model ANOVA using sides as a fixed factor and individual as a random one (Palmer & Strobeck, 1986). Accordingly, when the interaction between side-individual is significant (i.e., $MS_{error}<MS_{effect}$) it can be assumed that no measurement error was done.

RESULTS

Selecting FA traits

Three main characteristics have been identified to bias FA measures, and therefore should be considered in any FA study: measurement error, other kinds of asymmetry, and allometry (see Palmer, 1994). Results from measurement error analysis indicated that only the 1Claw and the 3TibiaL characteristics presented a high measurement error ($p>0.05$). These two traits were deleted from the analysis to avoid bias in the FA evaluation.

The rest of traits were used to check asymmetry. For each individual and trait we calculate the signed difference between left and right side (R_i-L_i). From the resulting data set, outliers (e.g., presence of deformities) were omitted to avoid distortions in FA detection (Palmer, 1994). To evaluate the viability to group sites (i.e., US, MS, DS), a non-parametric Kruskal-Wallis test was applied to |R-L| values of each trait and group. Because for each group none of the traits displayed significant differences ($p>0.05$), we considered these groups independently.

Several tests were performed with each group to detect FA from DA and AA: skewness, kurtosis, t-test, and visual observations from (R_i-L_i) distributions (see Annex 1 for results). Test for skewness and kurtosis have been considered very useful to distinguish Fluctuating Asymmetry (FA) from the other asymmetries, providing information about how a distribution departures from normality (Palmer & Strobeck, 1992). Any trait displayed Antisymmetry (AA), as kurtosis was positive for all cases. Directional Asymmetry (DA) were detected only for two traits: MandL for all group of sites and 1FemurW for downstream sites (DS) group. However, because 1FemurW only displayed DA in one occasion, we have assumed the possible presence of and Type I error. Therefore, FA was established for all traits except mandible (MandL); as the mean of the (R_i-L_i) were not different from 0 ($p>0.05$) and kurtosis were positive in all cases. However, kurtosis values were very high, being more typical of a leptokurtic than normal distribution, but this does not invalidate the assignation of the morphological traits measure to FA .

Once FA-traits are detected and because FA can be influenced by trait size (Palmer & Strobeck, 1986; Leung, 1988), r-Pearson correlations between |R_i-L_i| respect (R_i-L_i)/2 were performed for each FA trait. Results indicated that asymmetry in 1TibiaA ($r=-0.111$, $p=0.038$), 2Claw ($r=-0.202$, $p=0.003$), 3FemurW ($r=-0.189$, $p=0.001$) and 3Claw ($r=-0.210$, $p=0.004$) were significant associated with size, but having low correlation coefficient. Although size-dependency traits can be treated using specific FA-indexes (see Palmer, 1994), to facilitate data analysis only traits showing independency with size were retained.

To plot and compare levels of FA between sites, FA1 index (FA1=mean|R-L|) was applied (see Palmer, 1994). Differences between groups of sites were carried out applying a non-parametric Kruskal-Wallis test using |R_i-L_i| differences for each group of sites (Palmer & Strobeck, 1986). To check the extend of the influence of pollution on the asymmetry, FA levels were correlated with chemical variables using r-Pearson correlations.

Changes of asymmetry between sites and relationships with pollution

Overall, a downstream increase of asymmetry is presented by all traits, except in few cases (e.g., in 2FemurW). In some cases the extent of changes of FA1 downstream is different depending on the trait. All measured features from the first leg increase proportionally from upstream (US) to downstream (DS) sites. Besides, some traits from the second leg traits increase only from US sites to MS sites (midstream sites), whereas others in the third leg do it between MS and DS. Measured features from the first leg reach the maximum level of FA1 in downstream reaches compared with second and third leg traits. Patterns observed in Figure 3 agree with results from Kruskal-Wallis test (Table 2). Thus, for example, all traits present significant differences between US and DS sites, whereas only few traits are significant between US vs. MS or MS vs. DS sites. Some of the traits from the first and second leg display a significant increase of asymmetries between upstream and midstream sites, whereas others, mainly from the third leg, present lower asymmetries in middle than downstream sites (Table 2).

Table 2. Results from the Kruskal-Wallis non-parametric test (*p<0.05, **p<0.001).

Comparison	Trait	χ2	p-value	
US vs MS	**1FemurL**	6.669	0.0098	**
	1FemurW	4.3738	0.0365	*
	1TibiaL	1.8946	0.1687	
	2FemurL	0.8212	0.3648	
	2FemurW	9.6574	0.0019	**
	2TibiaL	5.7959	0.0161	*
	2TibiaW	1.5358	0.2152	
	2TarsusL	10.9316	0.0009	**
	2TarsusW	4.0861	0.0432	*
	3FemurL	1.5358	0.2152	
	3TibiaW	1.0874	0.297	
	3TarsusL	0.1035	0.7476	
	3TarsusW	2.4779	0.1155	

Comparison	Trait	χ2	p-value	
MS vs DS	**1FemurL**	0.8353	0.3607	
	1FemurW	3.8319	0.0503	
	1TibiaL	15.1879	0.0001	**
	2FemurL	3.0854	0.079	
	2FemurW	0.0533	0.8173	
	2TibiaL	3.743	0.053	
	2TibiaW	1.1584	0.2818	
	2TarsusL	0.0234	0.8784	
	2TarsusW	4.7999	0.0285	*
	3FemurL	2.2922	0.13	
	3TibiaW	4.7068	0.03	*
	3TarsusL	10.6543	0.0011	**
	3TarsusW	6.444	0.011	*

Comparison	Trait	χ2	p-value	
US vs DS	**1FemurL**	10.0501	0.0015	**
	1FemurW	11.4181	0.0007	**
	1TibiaL	16.4244	0.0001	**
	2FemurL	4.8875	0.0271	*
	2FemurW	10.3234	0.0013	**
	2TibiaL	12.2243	0.0005	**
	2TibiaW	3.9541	0.0468	*
	2TarsusL	11.3539	0.0008	**
	2TarsusW	10.506	0.0012	**
	3FemurL	5.2878	0.0215	*
	3TibiaW	6.4159	0.0113	*
	3TarsusL	5.0385	0.0248	*
	3TarsusW	8.8747	0.0029	**

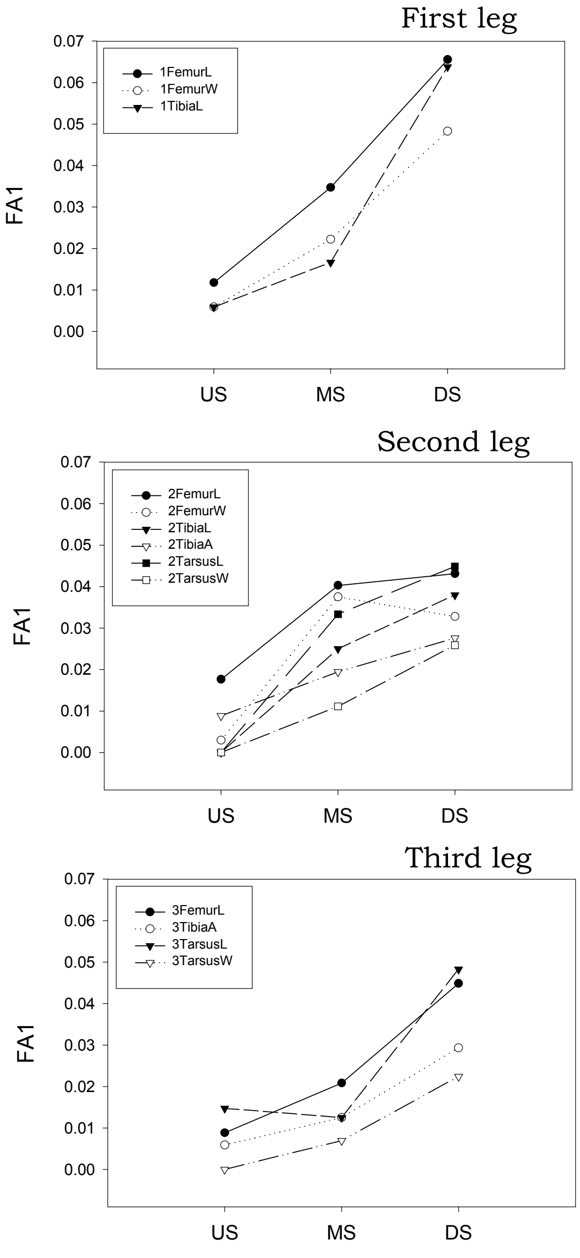


Figure 3. Levels of FA1 index between upper, middle and downstream sites. Each plot refers to traits measured in first, second and third leg respectively.

Similarly to levels of FA1, chemical parameters measured change downstream (Figure 4). Different patterns are observed for different variables. Values of suspended solids are similar between US and MS, but higher in DS sites. On the other hand, ammonium, P-phosphates, chloride and conductivity increase between upstream and middle reaches, remaining more or less constant in downstream reaches. It can not be observed differences downstream in N-nitrates and oxygen concentrations.

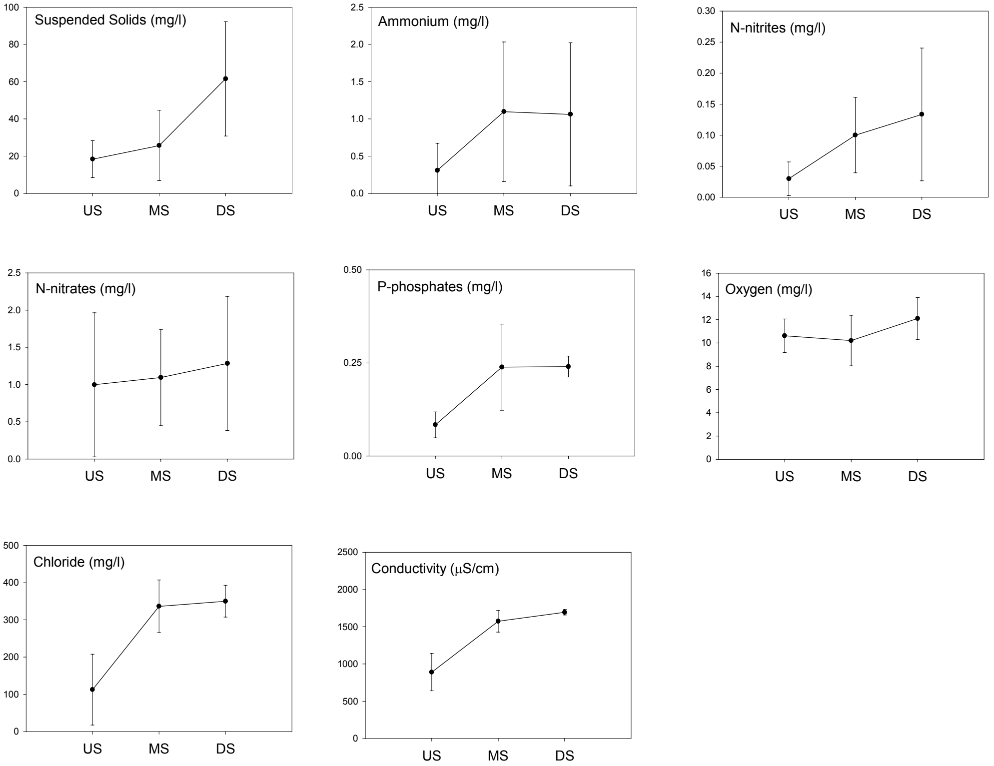


Figure 4. Mean and standard deviations of chemical variables between upper, middle and downstream reaches.

Comparing Figure 3 and 4, it appears that the increase of FA1 is related to some chemical parameters but not to others. When r-Pearson correlations are performed between chemical variables and measured traits, positive correlations result in all cases (see Table 3). However, only in few cases, significant values were obtained. Thus, suspended solids are related to an increase of asymmetry in all features except for second leg femur. Almost all traits are significantly correlated with salinity (i.e., chloride and conductivity). High concentrations of P-phosphates appear also correlated with most of the traits of the second leg, but not for the others.

Table 3. Pearson correlation coefficients (r) and p-values associated between measured traits and chemical parameters. Significant correlations are presented in bold.

		1FemurL	**1FemurW**	**1TibiaL**	**2FemurL**	**2FemurW**	**2TibiaL**	**2TibiaW**
Suspended Solids	*r-Pearson*	**0.635**	**0.646**	**0.673**	0.412	0.28	**0.536**	**0.581**
	p-value	**0.006**	**0.005**	**0.003**	0.101	0.276	**0.027**	**0.014**
Ammonium	*r-Pearson*	0.323	0.306	0.218	0.424	0.427	0.394	0.37
	p-value	0.206	0.232	0.4	0.09	0.088	0.118	0.144
N-nitrites	*r-Pearson*	0.487	0.475	0.402	0.503	0.454	0.521	0.514
	p-value	0.092	0.101	0.173	0.08	0.119	0.068	0.072
N-nitrates	*r-Pearson*	0.135	0.135	0.132	0.104	0.084	0.122	0.129
	p-value	0.619	0.617	0.625	0.701	0.757	0.651	0.635
Chloride	*r-Pearson*	**0.681**	**0.652**	**0.493**	**0.84**	**0.828**	**0.8**	**0.762**
	p-value	**0.003**	**0.005**	**0.044**	**0**	**0**	**0**	**0**
Oxygen	*r-Pearson*	0.291	0.306	0.363	0.093	0.002	0.191	0.233
	p-value	0.258	0.232	0.152	0.723	0.993	0.462	0.369
Conductivity	*r-Pearson*	**0.78**	**0.753**	**0.596**	**0.906**	**0.875**	**0.885**	**0.854**
	p-value	**0**	**0**	**0.012**	**0**	**0**	**0**	**0**
P-phosphates	*r-Pearson*	0.54	0.513	0.368	**0.684**	**0.682**	**0.646**	**0.612**
		0.107	0.129	0.296	**0.029**	**0.03**	**0.044**	**0.06**

		2TarsusL	**2TarsusW**	**3FemurL**	**3TibiaW**	**3TarsusL**	**3TarsusW**
Suspended Solids	*r-Pearson*	**0.491**	**0.634**	**0.658**	**0.666**	**0.652**	**0.662**
	p-value	**0.046**	**0.006**	**0.004**	**0.004**	**0.005**	**0.004**
Ammonium	*r-Pearson*	0.409	0.324	0.284	0.262	0.112	0.274
	p-value	0.103	0.205	0.269	0.31	0.67	0.288
N-nitrites	*r-Pearson*	0.519	0.488	0.458	0.44	0.303	0.45
	p-value	0.069	0.091	0.115	0.133	0.314	0.123
N-nitrates	*r-Pearson*	0.116	0.134	0.136	0.135	0.118	0.135
	p-value	0.669	0.62	0.617	0.618	0.664	0.617
Chloride	*r-Pearson*	**0.822**	**0.683**	**0.613**	**0.572**	0.292	**0.594**
	p-value	**0**	**0.003**	**0.009**	**0.016**	0.255	**0.012**
Oxygen	*r-Pearson*	0.154	0.29	0.324	0.339	0.396	0.331
	p-value	0.556	0.26	0.205	0.183	0.116	0.194
Conductivity	*r-Pearson*	**0.901**	**0.782**	**0.715**	**0.675**	0.392	**0.697**
	p-value	**0**	**0**	**0.001**	**0.003**	0.12	**0.002**
P-phosphates	*r-Pearson*	**0.666**	0.541	0.478	0.441	0.185	0.461
		0.035	0.106	0.163	0.202	0.609	0.18

DISCUSSION

The high level of kurtosis and the high skewness values found in some characters, even though the mean of R-L differences were not different from zero, may be related to the precision of the measurement system used (see Cuervo, 2000). A lower precision system may only display big differences in R-L measures and overlook the small ones, whereas in very precise systems rarely an individual displays in a trait a R-L of 0 although the global mean is not different of 0. However, independently of the measurement technique used, Palmer & Strobeck (1992) pointed out that leptokurtic distributions might be obtained as a result of a mix of individuals with low and high FA or a mix of individuals with FA and AA, beeing very difficult to discern both situations. However, Leung & Forbes (1997) modeling FA found that leptokurtic distributions may be possible and therefore be subjected to environmental stress, as the ideal FA does. Likely, a repercussion of the use of a less precise measurement method is an underestimation of the real level of FA in a population, although that is not a problem when levels of FA in a population are used to compare with others or to relate them to environmental variables.

Hydropsyche exocellata is a very pollution tolerant caddisfly in the Iberian Mediterranean area (González del Tánago & García de Jalón, 1984; Millet & Prat, 1984; Gallardo, 1994; Bonada *et al.*, Chapter 8). This species has been found in very saline environments in the south of Spain, until 8400 μS/cm (Gallardo, 1994). However, few is known about the status of the populations subjected to different water pollution levels. In our study we have observed that although *H. exocellata* is able to survive to relatively high pollution levels, the developmental stability is lower downstream with the increasing of pollution. From all measured chemical variables, salinity and suspended solids appear to influence the asymmetry of almost all traits, whereas phosphates only affects to specific characters. The large number of morphological characters and environmental variables measured in this study support the suggestion made by several authors that to determine the relationship between asymmetry and pollution, a large set of variables, as FA can not be detected by all environmental stressors individually (Leary & Allendorf, 2000; Clarke *et al.*, 1995; Hogg *et al.*, 2001). In that sense, Clarke *et al.* (1995) pointed out that FA is the result of the combined effect of several environmental variables rather than single ones. For example in a study in the asymmetry of adults of *Hexagenia rigida* in Canadian lakes, Dobrin & Corkum (1999) did not find a relationship between PCB concentrations in lakes and FA in mayflies. Consequently, they pointed out that the relationship between FA and PCB could be masked by the effects of other non-measured factors. Similarly, Hogg *et al.* (2001) looking at the effect of small temperatures shifts on meristic traits on *Nemoura trispinosa* did not found significant results. One of the explanations provided by the authors is that it might be possible that a high FA in control sites was present by non-measured stressors which effects are unable to separate from the temperature.

Few is known about the mechanisms that enhance development instability under environmental stress and how this is translated to asymmetries in the individuals (but see Emlen, 1993). Consequently, difficulties are found to interpret why some chemical variables are related to FA instead of others, and to discern if there is a direct of an indirect effect of the factor over the development. Suspended solids, salinity and phosphates are the most significant variables to explain an increase of FA in *H. exocellata* in Llobregat River.

When populations are compared, one of the difficulties is to select the characters to be used and to know if results will vary depending on the character (Leary & Allendorf, 1989; Lajus, 2001). Therefore it is necessary to use multiple traits to obtain reliable results (Watson & Thornhill, 1994), although it has been observed reviewing literature that is unlikely that the positive relationship between FA and stressors depend on the number of traits analyzed (Hogg *et al.*, 2001). Consequently, although it is recommended to use several traits to test for FA in relation to stress, our results suggest that at least for *H. exocellata*, few traits may be enough. This could simplify the harsh work of measure FA, and make the method more efficient, effective, easy to use and low in cost to be applied in biomonitoring programs, as it has pointed out by Clarke (1993). In that sense, fluctuating asymmetry has been identified as an easy and efficient method to assess the population status before its extinction by increasing environmental stress (Leary & Allendorf, 1989; Clarke, 1993, 1994, 1995), and therefore in that sense, it could be a useful tool for a proper management of aquatic systems.

In the lower parts of the Llobregat river, *H. exocellata* can survive although an increase of asymmetry is detected compared with upper reaches. Our data suggest that fluctuating asymmetry could be used as an early warning system of the disappearance of this species, which has been considered very important for river processes (see Soler & Puig, 1999). Because a high biological stress of larvae have been identified in lower Llobregat reaches, the presence of this species in these localities may be instable. It would seem improbable that larvae can disappear because to the increase of the high asymmetry itself, unless that functional traits are highly affected constraining the survival of larvae or the moulting to another instar. More work should be done to detect asymmetry in functional characters. Moreover, experimental work is needed to quantify the pollution threshold from where the population developmental patters are highly instable.

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Annex 1. Values of mean (R_i-L_i), skewness and kurtosis with standard errors. Results from the t-test and the p-value associated are also presented.

US	Mean	SE	Skewness	SE	Kurtosis	SE	t	p-value
1FemurL	0	0	2.42	0.41	15.5	0.8	0	1
1FemurW	-0.0062	0	-3.79	0.41	13.22	0.8	-1.438	0.161
1TibiaL	0.0071	0	3.51	0.44	11.18	0.85	1.441	0.161
1TibiaW	-0.0103	0	-0.29	0.43	1.45	0.84	-1.14	0.264
2FemurL	0	0.01	-1.48	0.44	7.17	0.85	0	1
2FemurW	-0.0033	0	-5.47	0.42	30	0.83	-1	0.326
2TibiaL	0	0	-	-	-	-	-	-
2TibiaW	-0.0034	0	-0.77	0.43	8.02	0.84	-0.571	0.573
2TarsusL	0	0	-	-	-	-	-	-
2TarsusW	0	0	-	-	-	-	-	-
2Claw	0.0111	0.01	3	0.71	9	1.39	1	0.347
3FemurL	0.012	0	2.49	0.46	4.56	0.9	1.809	0.083
3FemurW	-0.0035	0	-5.29	0.44	28	0.85	-1	0.326
3TibiaW	0.0086	0	3.14	0.48	8.6	0.93	1.447	0.162
3TarsusL	-0.0125	0.01	-1.98	0.47	6.86	0.91	-1.141	0.266
3TarsusW	0	0	-	-	-	-	-	-
3Claw	-0.01	0.01	-3.16	0.68	10	1.33	-1	0.343
MandL	0.4333	0.03	0.2	0.44	1.43	0.87	12.679	0

MS	Mean	SE	Skewness	SE	Kurtosis	SE	t	p-value
1FemurL	-0.0014	0	-1.17	0.28	4.83	0.56	-0.178	0.859
1FemurW	0.0085	0	0.27	0.28	1.45	0.56	1.514	0.135
1TibiaL	0.009	0	1.39	0.29	5.64	0.58	1.623	0.109
1TibiaW	-0.0061	0	-0.59	0.29	2.25	0.58	-0.839	0.375
2FemurL	0.02	0.01	3.86	0.29	23.99	0.58	1.275	0.207
2FemurW	0.0164	0	0.93	0.29	3.28	0.57	1.744	0.086
2TibiaL	0.009	0	2.65	0.29	12.66	0.58	0.948	0.347
2TibiaW	-0.0061	0	-0.93	0.29	0.18	0.58	-1	0.321
2TarsusL	0.021	0.01	1.58	0.31	4.17	0.62	1.997	0.051
2TarsusW	-0.007	0	-0.85	0.31	4.26	0.62	-1.427	0.159
2Claw	-0.0157	0.01	-1.14	0.38	1.98	0.74	-1.356	0.183
3FemurL	-0.005	0	-0.01	0.31	4.56	0.61	-0.685	0.496
3FemurW	0.0083	0	0.39	0.3	4.04	0.6	1.043	0.301
3TibiaW	-0.002	0	-0.12	0.33	2.94	0.66	-0.33	0.743
3TarsusL	0.006	0	3.1	0.33	17.19	0.66	0.771	0.444
3TarsusW	0.0063	0	1.38	0.34	6.66	0.68	1.353	0.183
3Claw	0.035	0.02	5.14	0.37	29.49	0.73	1.663	0.104
MandL	0.403	0.01	-0.76	0.29	1.4	0.58	26.823	0

DS	Mean	SE	Skewness	SE	Kurtosis	SE	t	p-value
1FemurL	0.0037	0.01	-1.26	0.32	8.25	0.63	0.204	0.839
1FemurW	0.029	0.01	1.62	0.32	5.11	0.63	2.466	0.017
1TibiaL	0.0267	0.01	0.04	0.31	2.09	0.62	1.936	0.058
1TibiaW	0	0.01	0.19	0.32	2.92	0.63	0	1
2FemurL	-0.0017	0.01	0.47	0.31	3.43	0.62	-0.168	0.868
2FemurW	0.0052	0	-0.51	0.31	1.7	0.62	0.651	0.517
2TibiaL	0	0.01	-1.49	0.31	5.91	0.62	0	1
2TibiaW	-0.0035	0	0.6	0.31	2.68	0.62	-0.468	0.642
2TarsusL	-0.0037	0.01	0.46	0.32	7.21	0.64	-0.256	0.799
2TarsusW	0.006	0	0.04	0.33	0.48	0.66	0.771	0.444
2Claw	-0.0128	0.01	-1.68	0.37	5.37	0.74	-0.819	0.418
3FemurL	0.0279	0.01	2.19	0.36	6.36	0.7	1.576	0.123
3FemurW	0.0133	0.01	0.42	0.35	0.2	0.69	1.182	0.244
3TibiaW	0.0071	0.01	0.4	0.36	0.66	0.71	0.684	0.498
3TarsusL	0.025	0.01	1.29	0.37	3.71	0.73	1.325	0.193
3TarsusW	-0.0025	0	0	0.37	0.17	0.74	-0.274	0.786
3Claw	-0.0166	0.01	-0.81	0.42	1.65	0.83	-1	0.326
MandL	0.3755	0.03	-1.54	0.33	9.16	0.66	12.139	0

Conclusions

1. Two protocols differing in sorting procedures have been presented and compared, obtaining similar results. When samples are sorted in the lab, a subsample of 200 individuals is enough to obtain almost all families and a reliable biological index rank. However, depending on the objectives to achieve it should be considered the application of each protocol.

2. The field protocol developed in Spain can be applied satisfactorily in other mediterranean areas in the world, obtaining family richness, macroinvertebrate composition and biological quality values similar as the obtained in methods developed especially for those areas.

3. Convergences and divergences in the macroinvertebrate structure between mediterranean regions are related to historical and local factors. Mediterranean regions in northern hemisphere areas are highly convergent in macroinvertebrate structure, whereas southern hemisphere is divergent between them and with the northern ones.

4. Responses to temporality are less convergent between regions than habitat, indicating that the last is a more important constraining filter than temporality.

5. Temporality modifies habitat characteristics changing the riffle-pools sequences of rivers. A gradient of sites and community composition is found between riffles, connected pools and isolated pools. Similar richness is found between the three macrohabitats, what jointly with the high specific community in isolated pools, suggest that isolated pools act as islands but not to refuges to riffles communities. Pools connected to riffles are an intermediate habitat between riffles and isolated pools.

6. Habitat and temporality are interconnected. Temporality changes habitat characteristics, and habitat induces temporality. Different levels of spatial and temporal heterogeneities are observed between permanent, intermittent and ephemeral reaches affecting macroinvertebrates. In all cases, differences in macroinvertebrates are found between wet and dry season. In the application of the idea from "River Habitat Template", mediterranean rivers present different biological traits depending on the reach condition: permanent, intermittent and ephemeral.

7. A total of 91 Trichoptera species in Iberian Mediterranean have been identified, extending the distribution areas of some of them and confirming the presence of some others. Relevant taxonomic and ecological information is presented. Along the Mediterranean coast and increase of the proportion of North African and endemic species is noticed through the south. European distribution species are dominant in all cases.

8. Distribution patterns observed in caddisfly along Iberian Mediterranean coast are heterogeneous in space and time. The factors implied are mixes of environmental variables acting at different scales from basins to habitat characteristics, being longitudinal river zonation and geology the most important. The highest richness was collected in Segura basin, with a mix of northern and southern species, what can be related to historical factors.

9. Optimums and tolerances of caddisflies at family and species level are presented for different variables related to pollution. These variables affect differently to each caddisfly taxon. Ecological profiles patterns from families and species are similar for some taxa but not for others, depending on the number of species and the intolerance degree of family. An index to measure the degree of intolerance is presented to be used as a biological index of caddisflies.

10. Larvae of *Hydropsyche exocellata* present an increase of fluctuating asymmetry downstream for all measured traits, what it has been related to pollution levels. Salinity, suspended solids and phosphates are strongly related to asymmetry, but its importance it is different depending on each morphological trait.

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