

Index

- Abies* spp. (firs), 282
Abutilon theophrasti, 498
Acanthina angelica (whelk), 62
Acanthinucella spirata (predatory snail), 50
Aceria guerreronis (coconut mite), 438–439
Aceria tulipae (dry bulb mite), 437
Acremonium strictum, 263
Aculops lycopersici (mite), 439
Acyrtosiphon pisum (pea aphid), 31–36, 232, 399, 401, 453, 462
Adalia bipunctata (lady beetle), 453
 adaptive predator behavior, 135
 adaptive prey trait modification (APTM), 140
 and environmental stochasticity, 145–147
 future needs for APTM theory, 145–153
 gap between theory and experiment, 150–153
 in food web theory, 140–143
 in larger food web systems, 142–143
 in one predator–two prey webs, 142
 in predator–prey models, 140
 in tritrophic food chains, 141
 in two predator–one prey webs, 141–142
 influence on system dynamics, 143–144
 prey response to system dynamics, 147–148
 question of inclusion in ecological theory, 144–145
 role in ecological theory, 132–133
 scaling up insights to large webs, 148–150
 terminology, 135
 theoretical issues, 144
 See also modeling adaptive prey trait modification.
Aeshna umbrosa (dragonfly), 75, 76–77
Ageratina adenophora, 499
 Aleppo pine (*Pinus halepensis*), 284
Alexandrium minutum (microalga), 56–57
 alfalfa, 453, 455
 algae (marine), 50
 algal toxins, 56–57
 Allee effects, 91
Alliaria petiolata (garlic mustard), 459
Amblydromalus manihoti (predatory mite), 440–442
 amphipods, 18–19, 51
Amphiprion percula (clownfish), 59–60
Anagrus spp. (parasitoids), 482
Anax junius (dragonfly), 76–77
 anglerfishes, 404
Anopheles gambiae (mosquito), 401
 antibiotic compounds in corals, 400
 ants, 112
 effects of plants on, 15, 18
 Formica japonica, 169–170
 parasitoids, 23
 Pheidole diversipilosa, 36–37
Aphelinus asychis (parasitoid), 461
Aphidius ervi (parasitoid), 31–36, 401, 453
 aphid–parasitoid system, 40
 trait-mediated trophic cascades, 38–40
 aphids
 Acyrtosiphon pisum, 31–36, 232, 401, 453
 Aphis craccivora, 232, 453
 Brassica oleracea food webs, 41–42
 Brevicoryne brassicae, 112, 475
 cowpea aphid, 232, 453
 development of winged morph, 15, 442
 effects of parasitoid predators, 14, 23
 effects of parasitoid presence, 15
 influences on body size, 15
 Megoura viciae, 31–36
 Myzocallis asclepiadis, 112
 Myzus persicae, 112
 natural enemies, 452–454, 461, 462
 pea aphid, 31–36, 232, 399, 401, 453
 Pemphigus betae, 304–305, 306–307, 375, 382
 predation by coccinellids, 20
 secondary symbionts, 401
 Toxoptera citricida, 452
 Uroleucon nigrotuberculatum, 169–170
 Uroleucon rudbeckiae, 122–124
Aphis craccivora (cowpea aphid), 232, 453
Apocephalus ‘sp.8’ (parasitoid), 36–37
 apparent competition, 10, 19–20, 140
 between prey, 142
 applied ecology, 528
 summary of consequences of TMIs, 528
 aquatic ecosystems, 400
 microbially mediated TMIs, 399–400
 protective symbioses, 399–400
Arabidopsis thaliana, 383

- arbuscular-mycorrhizal fungi, 261–264
- arthropod communities, 167
- effects of herbivore-initiated bottom-up cascades, 162–167
 - interspecific indirect genetic effects (IIGEs), 308–309
- Ascophyllum nodosum* (seaweed), 58
- Asian citrus psyllid (*Diaphorina citri*), 452
- aspen (*Populus* spp.)
- effects of wolf reintroduction, 13, 37
 - genotypes, 373
- augmentative biological control, 461
- use of enemy functional diversity, 460–461
- Avena fatua*, 491
- Baccharis*, 296
- Baccharis salicifolia*, 122–124
- barnacles, 50
- (*Semibalanus balanoides*), 330, 331
 - effects of whelk predation, 15
 - predator-induced morphological change, 62
- bass habitat shift, 22
- beaver (*Castor canadensis*), 287, 300, 303
- interspecific indirect genetic effects (IIGEs), 308–309
- beetles, 37, 179
- Galerucella californiensis*, 37
 - Galerucella tenella*, 37
 - ground beetles, 453
 - Ips typographus*, 349
 - Mordellistena convicta*, 245, 247–248, 251–252
 - Trirhabda virgata*, 348
- behavioural flexibility
- influence on community dynamics, 42–43
- behavioural plasticity, 11–12
- trait-change mechanism, 16
- behaviourally mediated indirect effects, 135
- Bemisia tabaci* (whitefly), 442
- Bifidobacterium*, 402
- biodiversity
- and ecosystem functioning, 414–415, 424–425
 - and resistance to invasion, 425–426
 - and robustness to resident extinctions, 425–426
 - consequences of herbivore-initiated bottom-up cascades, 178–179
 - importance of non-trophic interactions, 414–415
 - importance of TMIs, 414–415
- biological control
- and natural enemy biodiversity, 451–452
 - augmentative biological control, 460–461
 - classical biological control, 459
 - conservation biological control, 460–461
 - herbivore-induced indirect plant defence, 436–439
 - influence of trait-mediated effects, 445–446
 - mathematical models, 446
 - plant-mediated competition among herbivores, 443–445
 - predator-induced escape behaviour of herbivores, 439–442
 - predator-induced ontogenetic escape by herbivores, 442–443
 - predator-mediated competition among herbivores, 443–445
 - trait changes in tritrophic systems, 435–436
 - use of enemy functional diversity, 459–461
 - weeds, 454, 456
 - See also* natural enemies.
- biological invasions. *See* invasive species
- black-capped chickadee (*Parus atricapillus*), 245, 247, 347, 349
- black locust (*Robinia pseudoacacia*), 264
- blue crab (*Callinectes sapidus*), 54, 57–58
- body size, 15
- indirect effects on, 1, 15
- Boloria titania* (butterfly), 514
- Botanophila seneciella* (ragwort seed head fly), 454
- bottlenose dolphins, 50
- bottom-up cascading effects, 181
- future research directions, 180–181
 - observed trends, 180–181
- bottom-up trophic cascades
- herbivore initiation, 162–164
 - initiated by a stem borer in a willow system, 167–168
 - initiated by aphids in a goldenrod system, 169–170
 - initiated by belowground microbe in a soybean system, 170–171
 - initiated by microbial symbionts, 170–171
- Brassica oleracea* aphid-parasitoid food webs, 41–42
- Brassica oleracea* var. *gemmifera* (Brussels sprouts), 112
- Brevicoryne brassicae* (aphid), 112, 475
- broad-sense community heritability, 311
- Bromus diandrus*, 491
- Bromus tectorum* (grass), 232
- brown citrus aphids (*Toxoptera citricida*), 452
- Brussels sprouts (*Brassica oleracea* var. *gemmifera*), 112
- bryostatins, 399
- Bugula neritina* (bryozoan), 399
- bullfrogs, 22
- bur oak system, 349–350
- Burkholderia* spp., 403
- Busycon carica* (knobbed whelk), 57–58
- butterflies, 470
- Boloria titania*, 514
 - Iolanta iolas*, 470
 - Pieris* spp., 483
- C:N:P cycling in ecosystems, 332–333
- Callinectes sapidus* (blue crab), 54, 57–58
- Cancer* spp. (crabs), 58–59
- candidate genes, 297, 302–304
- definition, 316
- cannibalistic conspecifics, 74–75, 81

- Cape gannet (*Morus capensis*), 515–516
- Carcinus maenus* (green crab), 50, 52, 55, 57, 58–59, 330, 331
- caribou (*Rangifer tarandus*), 518
- Carpobrotus edulis*, 499–500
- carvacrol, 495
- cassava green mite (*Mononychellus tanajoa*), 440–442
- Castor canadensis* (beaver), 287, 300, 303
interspecific indirect genetic effects (IIGEs), 308–309
- Centaurea diffusa* (diffuse knapweed), 456
- Centaurea stoebe*, 500–501
- Cerastoderma edule* (cockle), 57
- Cervus elaphus* (elk), 13, 18, 37, 518
- Geutorhynchus constrictus*, 459
- Geutorhynchus scrobicollis*, 459
- Chamerion angustifolium* (fireweed), 261
- cinnabar moth (*Tyria jacobaeae*), 454
- citrus leafminers (*Phyllocnistis citrella*), 452
- citrus pests
range of specialist natural enemies, 452
- clams, 50
Macoma balthica, 57
Mulinia lateralis, 57
- Clark's nutcracker (*Nucifraga columbiana*), 279–281, 282–283
- Clavicipitaceae (endophytic fungi), 402
- climate change, 462
and the match/mismatch hypothesis, 511–512
driver of phenological trait shifts, 508–509
future research directions, 520–522
impacts on migratory species, 516–518
impacts on natural enemy functional diversity, 461–462
resource abundance variation, 512–513
spatial mismatch in consumer–resource interactions, 513–518
- Clupea* spp. (herring), 59, 509
- Coccinella septempunctata* (lady beetle), 462
- Coccinella transversoguttata* (lady beetle), 452
- coccinellids, 20
- cockle (*Cerastoderma edule*), 57
- coconut mite (*Aceria guerreronis*), 438–439
- cod (*Gadus* spp.), 509
- coevolution, 207
broad definition, 207
diffuse coevolution, 208
geographic mosaic theory, 208
Janzen's definition, 207–208
origin of the term, 207
pairwise coevolution, 207–208
summary of consequences of TMIs, 527
- coevolutionary process and TMIs, 218
conceptual and theoretical importance, 217–218
future research directions, 217–218
- coevolutionary theory and TMIs, 209–217
diffuse coevolution, 217
geographic mosaic theory and TMIs, 214–217
hot and cold spots, 217
selection mosaics, 217
TMIs and pairwise vs. diffuse interactions, 211–212
- coevolutionary TMIs, 208
examples of influence of TMIs, 209–210
origins of, 207–208
requirements for pairwise coevolution, 208–209
- Coleomegilla maculata* (lady beetle), 453, 455, 456
- Coleoptera, 28
- collard (*Brassica oleracea*), 453
- Collembola, 357
- Colorado potato beetle (*Leptinotarsa decemlineata*), 456
- common periwinkle (*Littorina littorea*), 13, 61
- communities
effects of individual plant genotypes, 371–377
importance of trait- vs. density-mediated indirect effects, 9–10
non-additive effects of plant genotype diversity, 382–384
summary of consequences of TMIs, 526–527
taxonomic framework for TMIs, 10–25
- community, 316
definition, 316
- community composition, 296, 316
- community diversity, 296, 316
effects of phenotypic plasticity, 491
- community dynamics
density interactions, 2–3
influence of behavioural flexibility, 42–43
- community ecology
potential contribution of APTM, 153–154
recognition of indirect effects, 1–2
traditional pairwise approach to interactions, 131
- community evolution
evolutionary indirect interactions, 253–255
- community genetics, 295–297, 300, 316
- community genomics, 301–302, 316
- community heritability, 311, 316
quantification, 300
- community interactions and IIGEs, 304–307
- community-level selection, 311–314, 317, 452, 455
simulation approach, 311–314
- community phenotypes, 305, 310–311, 316
- community properties
influence of TMIs, 295–297
- community stability, 296, 317
- community structure
effects of microbially mediated TMIs, 404–405
effects of trait-mediated interactions, 40–42
- comparative genomics, 315, 317
- cones
trait evolution, 278–279
variations in DMIs and TMIs, 281–284

- conifers
 - disc loading of seeds, 285
 - evolutionary consequences of TMIs, 279–281
 - reproductive trait evolution, 278–279, 285–287
 - role of DMIs and TMIs in trait evolution, 281–284
 - selection pressures on serotiny, 285–287
- connectance, 42
 - and species diversity, 41–42
- conservation biological control
 - use of enemy functional diversity, 460–461
- conspecific cannibalism, 74–75
- consumer–resource interactions
 - impacts of phenological asynchrony, 509
 - phenological shift and spatial mismatch, 513–518
- consumptive competition, 19–20
- context-dependent effects, 2
- copepods, 56–57
- coral probiotic hypothesis, 400
- coral reefs, 59
- cordgrass
 - induced defenses, 16
- cordgrass (*Spartina alterniflora*), 61
- core species, 296
- corn (*Zea mays*), 453, 496
- Cotesia glomerata* (parasitoid), 30–31, 483
- cottonwoods (*Populus* spp.), 279, 287
 - genomic sequencing, 301–302
 - interspecific indirect genetic effects (IIGEs), 308–309
- cowpea aphid (*Aphis craccivora*), 232, 453
- crab predation, 21
- crabs (*Cancer* spp.), 58–59
- crayfish, 21
- crickets, 37
- crossbills, 216–217
- Cytisus scoparius*, 230

- damage-induced volatiles
 - effects on herbivore densities, 467
- damsel bug (*Nabis americanoferus*), 452
- Darwin, Charles, 207
- decomposers, 340
 - effects of herbivore TMIs, 352–353
- defense induction in plants, 349–351
- defoliation-induced root exudation of labile C, 346
- Delphacodes scholochloa* (planthopper), 482
- demography, 89
 - influence of traits, 89
- density dependence
 - Allee effects, 91
 - analysis of trait-mediated effects, 101–103
 - and trait-mediated interactions, 90–94
 - discrete-time model of trait-mediated effects, 100–101
 - influence of trait plasticity, 101
 - influence on stability of ecosystems, 89
 - positive density dependence, 91
- density interactions, 2–3
- density-mediated biotic indirect effects, 417
- density-mediated effects
 - in marine systems, 47–48
- density-mediated indirect effects (DMIEs), 12
 - comparison with trait-mediated indirect effects, 9–10, 415–416
 - definition, 135, 237
- Desmarestia ligulata* (seaweed), 63
- detritivores, 340
 - effects of herbivore TMIs, 353–354
- detritus-based food chains, 325
- developmental plasticity, 11–12
 - trait-change mechanism, 16–17
- developmental stage variation within species, 70
- Diadegma* spp., 479
- Diaeretiella rapae* (parasitoid), 475
- diamond back moth (*Plutella xylostella*), 30–31, 479
- diapause in spider mites, 442–443
- Diaphorina citri* (Asian citrus psyllid), 452
- Diaprepes abbreviatus* (weevil), 452
- diffuse coevolution, 208, 211–212, 217
- diffuse knapweed (*Centaurea diffusa*), 456
- dimethyl sulfide (DMS)
 - release by grazing zooplankton, 57
- dimethyl sulfioproponate (DMSP), 57
- dinoflagellates, 400
- Diorctria albovittella* (stem-boring moth), 349
- Diptera, 28
- direct density dependence
 - modelling trait-mediated effects, 95–100
- discrete-time model
 - trait-mediated density dependence, 100–101
- dog whelk (*Nucella lapillus*), 52, 55
- dominant (foundation) species, 279, 296
- downy woodpecker (*Poecile pubescens*), 245, 247
- dragonflies
 - Aeshna umbrosa*, 75–77
 - Anax junius*, 76–77
 - Plathemis lydia*, 76
 - size-structured interactions among larvae, 76
 - stage-structured mutual predation, 76–77
- dry bulb mite (*Aceria tulipae*), 437
- dugongs, 50

- eastern hemlock, 301
- eco-evolutionary feedback, 237
- ecological engineers, 135
- ecological theory
 - adaptive prey trait modification (APTMs), 132–133
 - food web theory, 133–135
 - foraging theory, 132
 - higher-order interactions (HOIs), 131–135, incorporating habitat-mediated effects, 429
 - incorporating non-trophic interactions, 429

- ecological theory (cont.)
 incorporating the interaction web model, 429
 incorporating trait-mediated effects, 429
 potential contribution of APTM, 153–154
 traditional pairwise approach to interactions, 131
- ecological traps, 516
- ecosystem
 definition, 317
- ecosystem engineering
 application of the interaction web model, 429
 herbivore-induced plant phenotypes, 171–174
- ecosystem engineers, 18, 170, 296, 418
- ecosystem functioning
 and biodiversity, 414–415, 424–425
 interaction web model, 415, 418–420, 421–423
 kinds of indirect effects, 415–418
 link between species richness and species interactions, 421–423
 relationship to ecosystem structure, 428–429
 role of non-trophic interactions, 414–415
 role of TMIs, 414–415
- ecosystem genetics, 300, 316
- ecosystem genomics, 301–302, 316
- ecosystem heritability, 316
- ecosystem phenotypes, 306, 316
- ecosystem processes, 307
 and IIGEs, 304–307
 defence induction in plants, 349–351
 effects of green-fall, 345
 effects of herbivore cadavers, 344–345
 effects of herbivore TMIs in soil systems, 352–354
 effects of herbivore faeces and urine, 343–344
 effects of predator-induced fear in prey, 326–328
 effects of premature leaf abscission, 345
 effects of selective foraging, 346–349
 effects of through-fall, 345
 effects on soil microclimate, 351–352
 effects on soil resources, 352
 fast-cycle effects, 341–343, 351–352
 herbivore-induced root exudation of labile C, 346, 495
 herbivore influences, 339–341
 herbivore influences on nutrient recycling, 349–351
 herbivore TMIE impacts in soil systems, 354–355
 impact of individual plant genotypes, 377–381
 influences on litter decomposition, 349–351
 mechanisms of herbivore influence, 341
Quercus (oak) ecosystems herbivore TMIs study, 355–357
 slow-cycle effects, 341–343
 slow-cycle pathways, 346–352
- ecosystem properties, 297
 influence of TMIs, 295–297
 interaction with invasive species, 427
- ecosystem structure
 relationship to ecosystem functioning, 428–429
- ecosystems
 consequences of energy flow in food chains, 328–330
 consequences of plant interactions, 492–495
 consequences of TMIs, 279–281
 effects of individual plant genotypes, 371–375
 effects of microbially mediated TMIs, 405–406
 factors affecting flows of energy and materials, 333–334
 non-additive effects of plant genotype diversity, 382–384
 nutrient constraints on energy transfer, 332–333
 summary of consequences of TMIs, 527–528
- Eichhornia crassipes*, 418
- elk (*Cervus elaphus*), 13, 18, 37, 518
- Elymus multisetus* (grass), 232
- Endobugula sertula* (bacterium), 399
- Endocrita excrescence* (stem-boring moth), 167–168
- endophytic bacteria, 22
- endophytic fungi
 interaction with mycorrhizae, 264
 symbioses, 402–403
- energy flow in food chains, 328–330
 factors affecting, 333–334
- energy transfer in ecosystems
 nutrient constraints, 332–333
- Epinephelus striatus* (Nassau grouper), 15, 59
- eriphyoid mites, 436–437
- Eucalyptus* spp., 301, 372
- Eucosma recissoriana* (lodgpole pine cone borer moth), 282
- Euplotidium* ciliates, 399
- European Phenology Network (EPN), 515
- European red mite (*Panonychus ulmi*), 443
- Eurosta* host races
 web of indirect interactions, 248–250
- Eurosta solidaginis* (gall fly), 244–245, 251–252
 mediation of enemy indirect interactions, 247–248
- Eurycea cirrigera* (salamander), 72
- Eurytoma gigantea* (parasitoid), 245, 247–248, 251–252
- evolution, 12
 as trait-change mechanism, 11–12
 trait-change mechanisms, 16
- evolution of increased competitive ability (EICA), 222, 229–230, 237
- evolutionary consequences of TMIs, 279–281

- evolutionary indirect effects, 221
 - change in invaders and natives, 221–223
 - definition, 237–238
 - evolution of increased competitive ability (EICA), 229–230
 - future research directions, 232–235
 - increased anti-herbivore defences in natives, 231–232
 - increased competitive ability in natives, 232
 - indirect ecological effects of invading species, 223–225
 - insights from study of invasive species, 235–237
 - loss of mutualism in invaders, 230–231
 - potential consequences of invading species, 225–232
 - study of biological invasions, 221
- evolutionary indirect interactions, 244
 - community evolution, 253–255
 - Eurosta solidaginis* mediates enemy interactions, 247–248
 - measuring indirect interactions, 245–253
 - reciprocal transplant experiments, 252–253
 - selection experiments, 253
 - testing indirect selection assumptions, 247
 - using geographic variation to test indirect selection, 251–252
 - web of indirect interactions of *Eurosta* host races, 248–250
 - web of indirect interactions of *Solidago* species, 248–250
- exploitative competition between predators, 141–142
- expressed sequence tags (ESTs), 302, 317
- extra-floral nectaries, 263, 265
- fear of predation
 - effects at ecosystem level, 326–328
- feeding traits, 13
- fire ants, 23
- fireweed (*Chamerion angustifolium*), 261
- firs (*Abies*), 282
- fish
 - predation on salamanders, 20
- fish stocks
 - match/mismatch hypothesis, 509–511
- flexible traits, 187
 - consideration in community modelling, 186–187
- food chains
 - C:N:P cycling, 332–333
 - connections between the bottom and the middle, 330–331
 - connections between the top and the middle, 331
 - consequences of foraging decisions in the middle, 326–328
 - detritus-based, 325
 - energy flow, 328–330
 - factors affecting flows through, 333–334
 - factors affecting length of, 327–328
 - length of, 327–328
 - predator-induced fear in prey, 326–328
 - trophic control from the middle, 325–331
- food web interactions, 3
- food web theory, 69
 - adaptive prey trait modification (APTM), 140–143
 - higher-order interactions (HOIs), 133–135
- food webs
 - diversity of species in the middle, 326
 - interactions in the middle, 326
- foraging theory, 132
- forest tent caterpillars, 382
- Formica japonica* (ant), 169–170
- foundation species, 279, 296, 297, 302, 317
 - as mediators of IIGEs, 301–302
 - influence of individual plant genotype, 371–373
- four species webs, 21–23
- fucoid algae, 50
- Fucus* sp. (seaweed), 17, 61
- functional diversity schemes
 - limitations of, 450–451
 - predicting enemy diversity effects, 457–459
- functional genomics, 315, 317
- Fundulus heteroclitus* (killifish), 57
- Gadus* spp. (cod), 509
- Gaillardia grandiflora*, 500–501
- Galeocerdo cuvier* (tiger shark), 50
- Galerucella californiensis* (beetle), 37
- Galerucella tenella* (beetle), 37
- gall fly (*Eurosta solidaginis*), 244–245, 247–248, 251–252
- gall-forming sawflies (*Phyllocolpa* spp.), 308
- garlic mustard (*Alliaria petiolata*), 459
- genetic basis for trophic interactions, 304–307
- genetic basis of TMIs, 297–301
- genetic fingerprinting, 302
- genetic maps, 297
 - organization of genomic information, 297
- Populus* spp., 302–303
- genetic similarity rule, 373
- genetic traits, 11
- genetic type, 108
- genetic variation terminology, 108
- genetics
 - community and ecosystem, 316
 - community genetics, 295–297
- genomic information
 - organization of, 297
- genomic sequencing
 - cottonwoods (*Populus* spp.), 302
- genomics
 - community and ecosystem, 301–302, 316
 - comparative genomics, 317
 - functional genomics, 317

- genomics research, 316
 relevance of interspecific indirect genetic effects (IIGEs), 314–316
- genotype, 108
- Geocoris* spp., 455
- geographic mosaic theory, 208, 214–217
- geographic variation
 testing the indirect selection hypothesis, 251–252
- Geranium sylvaticum*, 261
- gerbils, 22
- giant kelp (*Macrocystis pyrifera*), 63
- Glomus hoi*, 261
- goldenrod (*Solidago altissima*), 169–170, 379, 383, 384
- goldenrod (*Solidago rugosa*), 330
- goldenrod (*Solidago* spp.), 244–245, 296, 306, 348
 reciprocal transplant experiments, 253
 web of indirect interactions, 248–250, 252
- goldenrod–herbivore–natural enemy interactions, 244–245
- grass shrimp (*Palaemonetes pugio*), 57
- grasses
Bromus tectorum, 232
Elymus multisetus, 232
Paspalum dilatatum, 351
Poa pratensis, 495
Scolochloa festucacea, 482
Spartina pectinata, 482
- grasshoppers, 9, 13, 348, 455, 457, 462
- great tit (*Parus major*), 511
- green crab (*Carcinus maenas*), 50, 52, 55, 57, 58–59, 330, 331
- green-fall
 effects on ecosystem processes, 345
- groupers, 15
- guppy (*Poecilia reticulata*), 287
- gut microbacteria in vertebrates, 401–402
- gut microbes in humans, 373
- gypsy moth, 382
- Gyrinophilus porphyriticus* (salamander), 72
- habitat-mediated effects
 incorporation into theoretical ecology, 429
- habitat-mediated indirect effects, 417
- habitat selection traits, 13–14
- haddock, 59
- hairy woodpecker (*Picoides villosus*), 283
- Hamiltonella defensa*, 399, 401
- Haplopappus ericoides*, 499–500
- Haplopappus venetus* var. *seloides*, 499–500
- harbour seals, 50
- hard clam (*Mercenaria mercenaria*), 52–53, 57–58
- Harmonia axyridis* (lady beetle), 36, 453, 456, 461, 462
- herbivore density and patch size
 resource concentration hypothesis (Root), 466–467
- herbivore density distributions
 effects of damage-induced volatiles, 467
 influence of natural enemies, 467
- herbivore density distributions model, 467–468
 adding induced attraction to the model, 470–472
 adding natural enemies to the model, 472–479
 applied aspects, 482–484
 basic population model, 468–470
 density-dependent parasitoid emigration rates, 476–478
 field data, 479–482
 future research directions, 484
 insights from models, 484
 larval/pupal parasitoids and host attraction, 473–476
 predator-induced prey emigration, 478–479
- herbivore–enemy interactions, 127
 tritrophic perspective, 107–108
See also plant effects on herbivore–enemy interactions.
- herbivore-induced indirect plant defence, 15, 23, 31, 36, 37, 436–439
- herbivore-induced phenotypic plasticity in plants, 161–162, 230, 231
- herbivore-induced plant defences, 10, 13, 15, 16–17
- herbivore-induced plant phenotypes, 245
 changes in plant nutritional quality, 172
 damage-induced regrowth, 173
 ecosystem engineering, 173–174
 herbivore responses to, 174–176
 predator responses to changes in herbivores, 176–178
 resistance mediated by secondary metabolites, 171–172
 spatial and temporal resource mosaics, 179–180
 susceptibility mediated by secondary metabolites, 171–172
- herbivore-induced plant volatile chemicals, 20–, 20, 30–31
- herbivore-initiated bottom-up cascades, 231
 biodiversity consequences, 178–179
 effects on arthropod communities, 164–167
 future research directions, 180–181
 observed trends, 180–181
- herbivore suites, 223, 225, 234, 237
- herbivore TMIEs
 case study with *Quercus* (oak) ecosystems, 355–357
 defence induction in plants, 349–351
 ecosystem effects of cadavers, 344–345
 ecosystem effects of faeces and urine, 343–344
 ecosystem effects of green-fall, 345
 ecosystem effects of premature leaf abscission, 345
 ecosystem effects of through-fall, 345
 effects on decomposers (microbes), 352–353
 effects on detritivores, 353–354

- effects on soil microclimate, 351–352
- effects on soil resources, 352
- fast-cycle effects, 341–343, 351–352
- fast-cycle pathways, 343–346
- future research directions, 360–361
- importance for soil systems, 354–355
- induced root exudation of labile C, 346
- influence on litter decomposition rates, 349–351
- influence on nutrient recycling, 349–351
- relative importance of, 354–355
- selective foraging, 346–349
- slow-cycle effects, 341–343
- slow-cycle pathways, 346–352
- herbivores
 - influences on ecosystem processes, 339–341
 - mechanisms of influence on ecosystem processes, 341
- herring (*Clupea* spp.), 59, 509
- higher-order interactions (HOIs)
 - alternative terminology, 135
 - importance in ecological communities, 131–133
 - in food web theory, 133–135
- Holling type II functional response model, 186
- homeostatic adjustments, 17
- host–parasitoid interactions
 - effects of non-host species, 29–37
 - stability of, 29–37
 - trait-mediated trophic cascades, 37–40
- human gut microbes, 373
- human influences on marine systems, 58–60
- Human Microbiome Project, 402
- Hydrilla verticillata*, 303–304
- Hymenoptera, 28
- Hynobius retardatus* (salamander), 73
- Hypera brunneipennis*, 222–223, 231–232
- Hypericum perforatum*, 230–231
- Hypnea* sp. (seaweed), 63–64
- indirect ecological effects, 225
 - biological invasions, 223–225
- indirect effects
 - definition, 237
 - nature of, 1–2
- indirect genetic effects (IGEs), 299, 300, 317
- indirect selection hypothesis
 - testing assumptions, 247
 - using geographic variation to test, 251–252
- induced plant defences, 16–17
- induced plant volatile chemicals, 30–31
- induced responses
 - in plankton, 56–57
- induced volatiles
 - effects on herbivore densities, 467
- inducible defences
 - effects of ocean acidification, 59–60
- inducible responses
 - in marine systems, 47
- interaction modifications, 135, 416–417
- interaction web model, 415
 - application to ecological theory, 429
 - application to ecosystem engineering, 429
 - assessing ecosystem properties and species interactions, 420
 - biodiversity and ecosystem functioning, 424–425
 - biodiversity and resistance to invasion, 425–426
 - biodiversity and robustness to resident extinctions, 425–426
 - building the model, 418–420
 - ecosystem structure and functioning, 428–429
 - effects of interaction modifications, 422–423
 - effects of non-trophic interactions on biomass and production, 423–424
 - interaction between ecosystem properties and invasions, 427
 - link between species richness and species interactions, 421–423
 - non-trophic interactions and resistance to invasion, 427
 - non-trophic interactions and robustness to resident extinctions, 427
 - potential extension of applications, 429
 - species richness and connectance, 421
 - species richness and prevalence of interactions, 421
 - species richness and strength of interactions, 421–422
- interaction-web topologies, 17–23
 - consumptive competition/apparent competition, 19–20
 - future research directions, 24
 - taxonomic framework, 12
 - three-species web with non-trophic links, 20–21
 - tritrophic cascades, 17–19
 - webs with four or more species, 21–23
- interspecific indirect genetic effects (IIGEs), 301
 - and TMIs, 297–301
 - candidate gene approach, 302–304
 - community interactions and ecosystem processes, 304–307
 - cottonwoods, beavers and arthropod communities, 308–309
 - definition, 317
 - genetic and genomic basis for identification, 301–302
 - mediation by foundation species, 301–302
 - plant genotypes, 384–385
 - quantitative trait loci (QTL) analysis, 302–304
 - relevance for future research, 314–316
 - selection at community level, 311–314
 - selection within a community context, 310–311
- interspecific variation in plant traits, 125–126

- intraspecific genetic variation in plant traits, 125
- intraspecific variation, 69–70
- impacts of individual plant genotypes, 384–385
- introduced species
- in marine systems, 58–59
- invasive species
- and plant phenotypic plasticity, 498–501
 - biodiversity and resistance to invasion, 425–426
 - direct and indirect effects, 221
 - effects of non-trophic reactions on ecosystem responses, 425–427
 - evolution of increased competitive ability (EICA), 222
 - evolutionary change in natives and invaders, 221–223
 - impact on biodiversity, 414–415
 - in marine systems, 58–59
 - indirect ecological effects, 223–225
 - insights into evolutionary indirect effects, 235–237
 - interaction with ecosystem properties, 427
 - limiting factors, 230–231
 - mutualist-limited spread, 230–231
 - non-trophic interactions and resistance to invasion, 427
 - potential evolutionary indirect effects, 225–232
 - robustness to resident extinctions, 425–426, 427
- invasive species indirect effects
- evolution of increased anti-herbivore defences in natives, 231–232
 - evolution of increased competitive ability (EICA), 229–230
 - evolutionary loss of mutualism, 230–231, future research directions, 232–235
 - increased competitive ability in natives, 232
- invertebrates
- protective symbioses, 400–401
- Iolanta iolas* (butterfly), 470
- Iphisieus degenerans*, 439
- Ips typographus* (beetle), 349
- isopods, 20
- Jacobian matrix, 93–94
- Japanese brown frog (*Rana pirica*), 73
- jimsonweed, 111
- keystone species, 296
- killifish (*Fundulus heteroclitus*), 57
- kinds of traits, 13–15
- feeding, 13
 - future research directions, 23–24
 - life-history traits, 15
 - morphological traits, 15
 - physiological traits, 14–15
 - space use/habitat selection, 13–14
 - taxonomic framework, 11
- knobbed whelk (*Busyon carica*), 57–58
- lace bugs, 349–350
- lacewing larvae, 111
- lacewings, 455
- lady beetles
- Adalia bipunctata*, 453
 - as biological controls, 453–454, 455
 - Coccinella septempunctata*, 462
 - Coccinella transversoguttata*, 452
 - Coleomegilla maculata*, 453, 455, 456
 - Harmonia axyridis*, 36, 453, 456, 461, 462
 - Stethorus siphonulus*, 457
- leaf-rolling moth, 15, 22
- leaf trichomes, 108
- Leptinotarsa decemlineata* (Colorado potato beetle), 456
- Leucanthemum vulgare*, 263
- life-history strategies
- and the match/mismatch hypothesis, 519–520
- life-history traits, 14, 15
- lima bean (*Phaseolus lunatus*), 265
- limber pine (*Pinus flexilis*), 279–281, 285
- Listeria monocytogenes*, 401
- listeriosis, 401
- Lithophragma parviflorum*, 214–215
- litter decomposition rates
- influence of herbivores, 349–351
- Littoraria irrorata* (marsh periwinkle), 61
- Littorina littorea* (common periwinkle), 13, 61
- Littorina obtusata* (smooth periwinkle), 58
- lizards, 38
- locust (*Schistocerca* sp.), 400
- lodgepole pine (*Pinus contorta latifolia*), 216–217, 279, 283
- lodgepole pine cone borer moth (*Eucosma recissoriana*), 282
- Longitarsus jacobaeae* (ragwort flea beetle), 454
- loop analysis of trait-mediated effects, 102
- Lotka–Volterra equations and extensions, 69
- Lotka–Volterra model, 93, 95
- Lotus wrangelianus*, 222–223, 231–232
- Loxia curvirostra* (red crossbill), 283–284
- Lupinus sericeus*, 500–501
- Lycopersicon esculentum* (tomato), 263, 439, 443–445
- lygaeid bugs, 111
- Macoma balthica* (clam), 57
- Macrocystis pyrifera* (giant kelp), 63
- Manduca sexta*, 51
- mangrove, 301
- mantid species, 455
- mantis (*Tenodera angustipennis*), 455
- mantis (*Tenodera sinensis*), 455
- Mantis religiosa*, 455
- marine sponges, 400
- marine system TMIs
- cascading effects of predator avoidance, 54–58
 - cascading effects of predator avoidance beyond three species, 50–52

- consumer-induced TMIs between basal species, 62
- context-dependency, 52–54
- effects of predator cues, 55–56
- future research directions, 64
- human influences on indirect interactions, 58–60
- prey-induced TMIs between prey species, 63–64
- trait-mediated grazer–grazer interactions, 61–62
- types of experimental design, 49–50
- wider effects of TMIs, 60–64
- marine systems
 - density-mediated vs trait-mediated effects, 47–48
 - inducible responses and TMIs, 48
 - phyletic diversity, 48
 - proportion of generalist consumers, 48
 - range and consequences of TMIs, 47
 - top predator avoidance effects, 59
 - variety of inducible responses, 47
- marker–trait association studies, 302
- marsh periwinkle (*Littoraria irrorata*), 61
- match/mismatch hypothesis
 - and climate change, 511–512
 - future research directions, 520–522
 - integrating with life-history strategies, 519–520
- origins of, 509–511
- resource abundance variation, 512–513
- spatial mismatch, 513–518
- temporal variance and adaptation, 512–513
- mathematical model, 467
 - herbivore density and patch size, 466–467
- mayflies, 14, 19
- measuring indirect interactions, 247
 - structured equation modelling, 246–247
 - testing indirect selection assumptions, 247
- Medicago polymorpha*, 222–223, 231–232
- Megoura viciae* (aphid), 31–36
- Mercenaria mercenaria* (hard clam), 52–53, 57–58
- metabolic theory of ecology, 333
- microbial symbionts, 171
 - initiation of bottom-up trophic cascades, 170–171
- microbially mediated TMIs
 - aquatic ecosystems, 399–400
 - defining, 391–393
 - detecting, 391–393
 - distinction from DMIs, 391–393
 - ecosystem-level consequences, 405–406
 - effects on community structure and assembly, 404–405
 - examples of protective symbiosis, 393–404
 - future research directions, 408
 - pairwise species interactions, 404
 - predicting direction and strength, 406–408
 - protective symbioses in invertebrates, 400–401
 - protective symbioses in vertebrates, 401–402
 - terrestrial systems, 400–404
- migratory species
 - impacts of climate change, 516–518
 - potential for trophic mismatch, 516–518
- milkweed, 14, 112
- minnows, 22
- mite (*Aculops lycopersici*), 439
- model-based analysis of response surface designs, 193–200
 - characterizing flexible trait models, 193–196
 - extrapolation and estimation, 197–199
- modelling adaptive prey trait modification
 - incorporating trait modification into models, 138–139
 - incorporating traits into models, 135–138
 - modelling the dynamics of trait change, 139–140
- modelling communities
 - common experimental design, 188–189
 - consideration of flexible traits, 186–187
 - consideration of TMIs, 186–187
 - problems with the common experimental design, 189–191
 - static-trait communities, 191–193
- models. *See* herbivore density distributions model
- monarch butterfly, 14
- Mononychellus tanajoa* (cassava green mite), 440–442
- Mordellistena convicta* (beetle), 245, 247–248, 251–252
- morphological traits, 15
- Morus capensis* (Cape gannet), 515–516
- mosquito (*Anopheles gambiae*), 401
- moth (*Greya politella*), 214–215
- mud crab (*Panopeus herbstii*), 52–53
- Mulinia lateralis* (clam), 57
- multispecies mutualisms, 258
 - categories of trait-mediated indirect effects, 260–266
 - future research directions, 272–273
 - impacts on plant ecology and evolution, 257–258
 - mechanisms for effects on hosts, 258–259
 - mediated by DMIs, 258
 - mediated by TMIs, 258–259
 - nutritional–nutritional mutualisms, 264
 - nutritional–protection mutualisms, 263
 - nutritional–transport mutualisms, 261–262
 - pollination and seed dispersal mutualism interactions (case study), 266–272
 - pollination mutualisms, 265–266
 - protection–protection mutualisms, 265
 - protection–transport mutualisms, 264–265
 - seed dispersal mutualisms, 266
 - transport–transport mutualisms, 265–266

- mussel (*Mytilus edulis*), 50
 mutualism
 evolutionary loss of, 230–231
 limitation on spread of invasive species, 230–231
 See also multispecies mutualisms.
 mutualistic ants, 18
 mycorrhizae, 230–231, 258, 259, 263, 264, 306
Mytilus edulis (mussel), 50, 331
Myzocallis asclepiadis (aphid), 112
Myzus persicae (aphid), 112
- Nabis americoferus* (damselfly bug), 452
Nabis spp., 455
 Nassau grouper (*Epinephelus striatus*), 15, 59
Nassella pulchra, 491
 natural enemies
 influence on herbivore density
 distributions, 467
 natural enemy biodiversity
 and biological control, 451–452
 natural enemy diversity effects
 predictive use of functional diversity, 457–459
 natural enemy functional diversity
 biological control applications, 459–461
 complementary foraging behaviour, 456–457
 complementary roles in pest species
 attacked, 452–453
 complementary roles in space, 453–455
 complementary roles in time, 455–456
 future research directions, 461–462
 impacts of climate change, 461–462
 natural enemy–herbivore interactions
 tritrophic perspective, 107–108
 natural systems
 tritrophic interactions, 107–108
 nematodes, 357
Steinernema spp., 404
Neoseiulus baraki (predatory mite), 438–439
Neoseiulus cucumeris (predatory mite), 437, 439
Neotyphodium endophyte, 404, 405
Nesticodes rufipes (spider mite), 457
 next generation sequencing, 315, 317
 niche divergence, 514
 Nicholson–Bailey model, 473
 nitrogen-fixing bacteria, 22
 interaction with mycorrhizae, 264
 non-additive outcomes
 community effects of plant genotype
 diversity (mixtures), 382–384
 nonconsumptive effects (NCEs), 135
 nonlethal effects, 135
 non-trophic interactions
 and resistance to invasion, 427
 and robustness to resident extinctions, 427
 effects on biomass and production, 423–424
 importance for biodiversity, 414–415
 incorporating into ecological theory, 429
 role in ecosystem functioning, 414–415
 non-trophic links
 three-species web, 20–21
 non-trophic responses
 effects on ecosystem responses to
 biological invasions, 425–427
Nucella lapillus (dog whelk), 55
Nucella lapillus (snail), 330, 331
Nucifraga columbiana (Clark's nutcracker), 279–281, 282–283
 nutrient constraints in ecosystems, 332–333
 nutrient recycling
 influences of herbivores, 349–351
 nutritional–nutritional mutualisms, 264
 nutritional–protection mutualisms, 263
 nutritional–transport mutualisms, 261–262
- oak (*Quercus douglasii*), 490
 oak (*Quercus leavis*), 378
 oak (*Quercus* spp.) ecosystems, 360
 herbivore TMIEs case study, 355–357
 ocean acidification, 59–60
Oenothera biennis, 296, 383
Olneya testata, 495
 one predator–two prey webs
 adaptive prey trait modification (APTM), 142
Opsanus tau (toadfish), 52–53
 optimal foraging theory, 41
 owls
 effects on gerbil prey, 22
- pairwise coevolution, 207–209, 211–212
Palaemonetes pugio (grass shrimp), 57
Panonychus ulmi (European red mite), 443
Panopeus herbstii (mud crab), 52–53
 paradox of enrichment, 140, 141
 parasites, 13
 effects on host fitness, 13
 parasitoid–aphid system
 trait-mediated trophic cascades, 38–40
 parasitoids, 23
Anagrus spp., 482
Aphelinus asychis, 461
Aphidius ervi, 31–36, 401, 453
Apocephalus 'sp.8', 36–37
Brassica oleracea food webs, 41–42
Cotesia glomerata, 30–31, 483
 density-dependent emigration rates, 476–478
Diaeretiella rapae, 475
 effects of non-hosts on foraging, 13
 effects of trait-mediated interactions, 40–42
 effects on aphid prey, 14, 15, 23
Eurytoma gigantea, 245, 247–248, 251–252
 host attraction for larval/pupal parasitoids, 473–476
 influences on body size, 15
 secondary, 23
 parsnip web worm, 217
Parus atricapillus (black-capped chickadee), 245, 247
Parus major (great tit), 511

- Paspalum dilatatum* (grass), 351
 pea aphid (*Acyrtosiphon pisum*), 31–36, 232, 399, 401, 453, 462
Pemphigus betae (aphid), 304–305, 306–307, 375, 382
 perch
 cannibalistic conspecifics, 81
 effects of habitat shift, 20
Periclista (sawfly), 355–357
Phaeocystis globosa (heteromorphic phytoplankton), 56
Phaseolus lunatus (lime bean), 265
Pheidole diversipilosa (ant), 36–37
 phenological asynchrony
 consequences for consumer–resource interactions, 509
 phenological shifts
 consequence of climate change, 512–513
 future research directions, 520–522
 resource abundance variation, 512–513
 spatial mismatch in consumer–resource interactions, 513–518
 phenological traits
 shifts driven by climate change, 508–509
 phenotypes
 community and ecosystem levels, 316
 phenotypic plasticity, 10
 and community diversity, 491
 nature of plastic responses, 489
 trait-change mechanisms, 11–12
 phenotypic plasticity in plants, 161
 and direct interactions, 495–496
 and exotic invaders, 498–501
 and indirect interactions, 496–498
 bottom-up trophic cascades, 162–164
 future research directions, 501
 herbivore-induced effects, 171–174
 induced by herbivores, 161–162
 influence on community diversity, 161
 plant-based resource variation, 161
 plastic responses of plants, 489–491
 range of herbivore-induced effects, 164–167
Pholistima auritum, 497–498
 phorid fly, 23
Phyllocnistis citrella (citrus leafminers), 452
Phyllocolpa spp. (gall-forming sawflies), 308
Phyllotreta spp., 471
 physiological traits, 14–15
 phytoplankton, 56
 Phaeocystis globosa, 56
 phytoseiid mites, 437
Phytoseiulus longipes (predatory mite), 444–445
Phytoseiulus macropilis (predatory mite), 444–445
Phytoseiulus persimilis (predatory mite), 436, 439–440
Picoides villosus (hairy woodpecker), 283
Pieris rapae (small white butterfly), 30–31
Pieris spp. (butterflies), 483
 pine squirrels (*Tamiasciurus* spp.), 279–284, 285–287
 pinfish, 18–19, 51, 54
Pinus albicaulis (whitebark pine), 285
Pinus contorta latifolia (lodgepole pine), 216–217, 279, 283
Pinus flexilis (limber pine), 279–281, 285
Pinus halepensis (Aleppo pine), 284
Pinus lambertiana (sugar pine), 285
Pinus ponderosa (ponderosa pine), 284
Pinus sylvestris (Scots pine), 283
 pinyon pine, 306
Pisaster ochraceus (sea star), 50–51
 plankton, 49
 predator-induced responses, 56–57
 release of dimethyl sulfide (DMS), 57
 zooplankton ciliates and flagellates, 56
 zooplankton vertical migrations, 55–56
 plant defence guilds, 225, 238
 plant effects on herbivore–enemy interactions, 108
 case studies, 118–124
 classification scheme, 110–113
 criteria for DMIs, 108–109
 criteria for TMIs, 108–109
 definitions and terminology, 108–109
 experimental approaches, 109–110
 future directions for research, 126–127
 interspecific variation in plant traits, 125–126
 interspecific variation in predator–herbivore interactions, 118–121
 intraspecific genetic variation in plant traits, 125
 intraspecific variation in predator–herbivore interactions, 121–124
 mechanisms, 110–113
 tritrophic forest food web, 118–121
 tritrophic perspective, 107–108
 plant genotype diversity (mixtures)
 non-additive community and ecosystem outcomes, 382–384
 plant genotypes
 effects of variations in foundation species, 371–373
 effects on communities and ecosystems, 371–375
 genotype-mediated linkages, 381–382
 importance of intraspecific variation, 384–385
 individual genotypes and communities, 375–377
 individual genotypes and ecosystem processes, 377–381
 interspecific indirect genetic effects, 384–385
 plant–herbivore systems, 3, 12
 plant interactions
 ecological consequences, 492–495
 indirect interactions, 492
 mechanisms of multispecies mutualist effects, 258–259
 negative direct interactions, 491
 plasticity and direct interactions, 495–496

- plant interactions (cont.)
 plasticity and exotic invaders, 498–501
 plasticity and indirect interactions, 496–498
 positive interactions (facilitation), 491–492
- plant-mediated competition among herbivores, 14, 476
- plant phenotypes
 damage-induced regrowth, 173
 herbivore responses to induced phenotypes, 174–176
 induced changes in nutritional quality, 172
 predator responses to changes in herbivores, 176–178
 resistance mediated by secondary metabolites, 171–172
 susceptibility mediated by secondary metabolites, 171–172
See also phenotypic plasticity in plants.
- plant symbioses
 aboveground, 402–403
 belowground, 403
- plant trichomes, 111
- planthoppers, 16, 61
Delphacodes scholochloa, 482
Prokelisia crocea, 482
Prokelisia sp., 61
- Plasmodium*, 401
- plasticity in traits, 2
- Plathemis lydia* (dragonfly), 76
- Plutella xylostella* (diamond back moth), 30–31, 479
- Poa pratensis* (grass), 495
- Poecile pubescens* (downy woodpecker), 245, 247
- Poecilia reticulata* (guppy), 287
- pollination 265–272
 effects of mycorrhizae, 261–262
- pollination mutualisms, 262
- Polygonum bistorta*, 514
- ponderosa pine (*Pinus ponderosa*), 284
- Populus angustifolia*, 111, 304, 306, 308–309, 371–373, 376, 379, 382
- Populus angustifolia* hybrids, 377
- Populus angustifolia* × *P. fremontii* hybrids, 111
- Populus fremontii*, 304, 308–309, 371–373, 377
- Populus* spp., 372, 374
 aspen, 13, 37
 aspen genotypes, 373
 cottonwoods, 279, 287, 301–302, 308–309
 ecosystem impacts of individual genotypes, 377–381
 effects of genotype mixtures, 383
 genetic maps, 302–303
 hybrids, 111, 304–307, 308–309, 371–373, 377
 impacts of individual genotypes, 376–377
 interspecific indirect genetic effects (IIGEs), 304–307
- Populus tremuloides*, 379, 384
- positive density dependence, 91
- predator avoidance
 effects in marine systems, 59
- predator cues
 effects in marine systems, 55–56
- predator-induced escape behaviour of herbivores, 439–442
- predator-induced fear in prey, 326–328
- predator-induced ontogenetic escape by herbivores, 442–443
- predator-induced prey emigration, 478–479
- predator-mediated competition among herbivores, 443–445
- predator–prey interactions
 indirect effects, 9
 size-structured TMIs, 71–72
- predator–prey models
 adaptive prey trait modification (APTMs), 140
- predators
 conspecific cannibalism, 74–75
 intimidation effects on prey, 13
 responses to changes in herbivores, 176–178
 size-structured interactions, 72–75
 stage-structured mutual predation, 76–77
- predatory birds, 38
- predatory mites
Amblydromalus manihoti, 440–442
Neoseiulus baraki, 438–439
Neoseiulus cucumeris, 437, 439
Phytoseiulus longipes, 444–445
Phytoseiulus macropilis, 444–445
Phytoseiulus persimilis, 436, 439–440
Typhlodromalus aripo, 440–442
- premature leaf abscission
 effects on ecosystem processes, 345
- prey
 size-structured interactions, 76
- prey–predator systems, 3
- probiotic bacteria, 400, 402
- Prokelisia crocea* (planthopper), 482
- Prokelisia* sp. (planthopper), 61
- protection–protection mutualisms, 265
- protection–transport mutualisms, 264–265
- protective symbioses
 aquatic ecosystems, 399–400
 in invertebrates, 400–401
 in plants (aboveground), 402–403
 in plants (belowground), 403
 in vertebrates, 401–402
 terrestrial systems, 400–404
- Pseudocardinia* (actinobacterium), 401
- Pycnopodia helianthoides* (sea star), 53
- qualitative analysis of trait-mediated effects, 102–103
- quantifying TMIs
 common experimental design, 188–189
 model-based analysis of response surface designs, 193–200
 parallels with static-trait communities, 191–193
 problems with the common experimental design, 189–191

- quantitative trait loci (QTL), 295, 297, 302–304
- quantitative trait loci (QTL) analyses, 317
- quantitative trait loci (QTL) linkage maps, 302
- Quercus* (oak) ecosystems
- herbivore TMIEs case study, 355–357
 - Quercus agrifolia* (oak), 497–498
 - Quercus douglasii* (oak), 490–491
 - Quercus leavis* (oak), 378
 - Quercus* spp., 372
- ragwort (*Senecio jacobaea*), 454
- ragwort flea beetle (*Longitarsus jacobaeae*), 454
- ragwort seed head fly (*Botanophila seneciella*), 454
- Rana pirica* (Japanese brown frog), 73
- Rangifer tarandus* (caribou), 518
- reciprocal transplant experiments, 252–253
- red crossbill (*Loxia curvirostra*), 283–284
- red-eyed treefrog, 84
- Regiella insecticola*, 401
- reindeer, 347
- resource abundance variation
- effects of climate change, 512–513
- resource concentration hypothesis (Root), 466–467
- resource mosaics, 179–180
- rhizobia, 230, 264
- trophic effects in a soybean system, 170–171
- Rhizopus microsporus*, 403
- Rickettsiella*, 401
- Robinia pseudoacacia* (black locust), 264
- roots
- herbivore-induced exudation of labile C, 346
- salamanders
- Eurycea cirrigera*, 72
 - Gyrinophilus porphyriticus*, 72
 - Hynobius retardatus*, 73
 - predation by fish, 20
 - size-specific interactions, 72
- Salix eriocarpa* (willow), 167–168
- Salix gilgiana* (willow), 167–168
- Salix serissaefolia* (willow), 167–168
- Salix* spp., 372
- salticid spiders, 111
- Sargassum filipendula* (seaweed), 51, 63–64
- Sargassum* sp. (seaweed), 18–19
- sawfly (*Periclista*), 355–357
- scallops, 54
- Schistocerca* sp. (locust), 400
- Sciurus* spp. (tree squirrels), 279–281
- Scolochloa festucacea* (grass), 482
- Scots pine (*Pinus sylvestris*), 283
- sculpin, 14
- sea stars, 50–51
- Pycnopodia helianthoides*, 53
- sea turtles, 50
- sea urchins, 63
- Strongylocentrotus franciscanus*, 53–54
 - Strongylocentrotus purpuratus*, 53–54
- seaweed, 400
- Ascophyllum nodosum*, 58
 - Desmarestia ligulata*, 63
 - Fucus* sp., 17, 61
 - Hypnea* sp., 63–64
 - Sargassum filipendula*, 51, 63–64
 - Sargassum* sp., 18–19
- seed dispersal mutualisms, 266–272
- seeds
- trait evolution, 278–279
 - variations in DMIs and TMIs, 281–284
- selection at community level, 311–314
- simulation approach, 311–314
- selection experiments
- measuring indirect interactions, 253
- selective foraging
- ecosystem effects, 346–349
- Semibalanus balanoides* (barnacle), 330, 331
- Senecio jacobaea* (ragwort), 454
- serotiny in conifers
- selection pressures on, 285–287
- Serratia symbiotica*, 399
- sharks, 59
- effects of loss of top predators, 59
- simple sequence repeats (SSRs), 302, 317
- single nucleotide polymorphisms (SNPs), 297, 302, 317
- size
- variation within species, 70
- size-structured populations, 15
- size-structured predators, 72–75
- size-structured TMIs, 70–85
- conspecific cannibalism, 74–75
 - effects on long-term dynamics, 80–82
 - effects on predator–prey interactions, 71–72
 - effects on short-term dynamics, 79–80
 - expanding the TMI concept, 82–83
 - future research directions, 83–85
 - intraspecific variation, 69–70
 - one-species system, 70
 - size and developmental variation within species, 69–70
 - size classes as distinct functional groups, 71–72
 - size-structured mutual predation, 76–77
 - size-structured prey, 76
 - structural vs. numerical changes, 77–79
 - two-species system, 70
- slow-growth/high-mortality hypothesis, 112
- small white butterfly (*Pieris rapae*), 30–31
- smooth periwinkle (*Littorina obtusata*), 58, 61
- snails, 50
- Acanthinucella spirata*, 50
 - Nucella lapillus*, 330, 331
- soil fauna
- effects of herbivore TMIEs, 353–354
- soil microbes
- effects of herbivore TMIEs, 352–353
- soil microbial communities
- impacts of *Populus* genotypes, 376–377
- soil microclimate
- effects of herbivores, 351–352

- soil resources
 - effects on herbivores, 352
 - soil systems
 - effects of herbivore TMIEs, 352–354
 - herbivore TMIEs study in *Quercus* (oak) ecosystems, 355–357
 - importance of herbivore TMIEs, 354–355
 - Solanum ptychanthum*, 51
 - Solidago altissima* (goldenrod), 169–170, 379, 383, 384
 - Solidago rugosa* (goldenrod), 330
 - Solidago* spp. (goldenrod), 244–245, 296, 306, 348
 - reciprocal transplant experiments, 253
 - web of indirect interactions, 248–250, 252
 - soybean
 - trophic effects of microbial symbionts, 170–171
 - space use/habitat selection traits, 13–14
 - Spartina alterniflora* (cordgrass), 61
 - Spartina pectinata* (grass), 482
 - spatial mismatch in consumer–resource interactions, 513–518
 - species diversity
 - and connectance, 41–42
 - species-level variation, 69–70
 - spider mites
 - Nesticodes rufipes*, 457
 - Tetranychus cinnabarinus*, 457
 - Tetranychus evansi*, 443–445
 - Tetranychus urticae*, 436, 439–440, 442–443, 443–445
 - spiders, 9, 13, 18, 37, 455, 457, 462, 482
 - squid, 400
 - squirrels, 216–217
 - stability of ecosystems
 - influence of adaptive prey trait modification (APT), 143–144
 - influence of density dependence, 89
 - influence of trait plasticity, 90–94
 - stage-structured indirect interactions, 72–77
 - Steinernema* spp. (nematodes), 404
 - stem-boring moths
 - Dioryctria albiovittella*, 349
 - effects on willows, 15, 22
 - Endoclyta excrescence*, 167–168
 - Stethorus siphonulus* (lady beetle), 457
 - stoneflies, 14
 - strangler figs, 230
 - Strongylocentrotus franciscanus* (sea urchin), 53–54
 - Strongylocentrotus purpuratus* (sea urchin), 53–54
 - structured equation modelling, 246–247
 - sugar pine (*Pinus lambertiana*), 285
 - symbiosis
 - plants (aboveground symbioses), 402–403
 - plants (belowground symbioses), 403
 - protective symbioses in invertebrates, 400–401
 - protective symbioses in vertebrates, 401–402
 - syrrhids, 455
 - tadpoles
 - effects of predator presence, 18, 19
 - effects of predators on, 22
 - response to predator cues, 73
 - Tamiasciurus* spp. (pine squirrels), 279–284, 285–287
 - taxonomic framework for TMIEs, 10–25
 - future research directions, 23–25
 - interaction-web topologies, 12, 17–23
 - kinds of traits, 11, 13–15
 - trait-change mechanisms, 11–12, 16–17
 - Tenodera angustipennis* (mantis), 455
 - Tenodera sinensis* (mantis), 455
 - terpenes, 494
 - terrestrial systems
 - protective symbioses, 400–404
 - Tetranychus cinnabarinus* (spider mite), 457
 - Tetranychus evansi* (spider mite), 443–445
 - Tetranychus urticae* (two-spotted spider mite), 436, 439–440, 442–443, 443–445
 - three-species web with non-trophic links, 20–21
 - through-fall
 - effects on ecosystem processes, 345
 - Thymus pulegioides*, 494
 - Thymus serpyllum*, 494
 - tiger shark (*Galeocerdo cuvier*), 50
 - effects of loss of, 59
 - time scales of trait-mediated effects, 94–95
 - TMIEs. *See* trait-mediated indirect effects
 - TMIEs. *See* trait-mediated indirect interactions
 - toadfish (*Opsanus tau*), 52–53
 - tomato (*Lycopersicon esculentum*), 263, 439, 443–445
 - Toxoptera citricida* (brown citrus aphids), 452
 - trait, 2
 - definition, 2
 - trait cascades, 18–19
 - trait-change mechanisms, 15, 16–17
 - behavioural plasticity, 16
 - developmental plasticity, 16–17
 - evolution, 16
 - future research directions, 24
 - taxonomic framework, 11–12
 - within-generation phenotype selection, 16
- trait evolution
- community and ecosystem consequences, 287–288
 - consequences of TMIEs, 279–281
 - examples and consequences of indirect interactions, 285–287
 - indirect genetic effects (IGEs), 299
 - influence of multispecies interactions, 278
 - influence on ecosystem interactions, 278
 - reproductive traits in conifers, 278–279
 - selection pressures from other species, 287–288
 - variations in DMIEs and TMIEs, 281–284
- trait invariance, 2
- trait-mediated biotic indirect effects, 417
- trait-mediated density dependence
- discrete-time model, 100–101

- trait-mediated direct effects, 418
- trait-mediated effects
 - direct density dependence model, 95–100
 - in marine systems, 47–48
 - incorporation into theoretical ecology, 429
 - methods of analysis, 101–103
 - timescales, 94–95
- trait-mediated indirect effects (TMIEs)
 - alternative terminology, 135
 - comparison with density effects, 9–10
 - comparison with DMIEs, 415–416
 - definition, 237
 - nature of, 1–2
- trait-mediated indirect interactions (TMIIs)
 - alternative terminology, 135
 - conditions required for, 3
 - consideration in community modelling, 186–187
 - definition, 3, 48, 317
 - expanding the concept, 82–83
 - extent of influence in communities, 3
 - implications for ecological studies, 3–4
 - requirements for, 19
 - types of effects, 3
- trait-mediated trophic cascades
 - host–parasitoid interactions, 37–40
- trait plasticity, 2
 - influence on density dependence, 101
 - influence on ecosystem stability, 90–94
- traits, 11
 - feeding traits, 13
 - influence on demography, 89
 - life-history traits, 15
 - morphological traits, 15
 - physiological traits, 14–15
 - space use/habitat selection, 13–14
 - taxonomic framework, 11
- transport–transport mutualisms, 265–266
- tree squirrels (*Sciurus* spp.), 279–281
- Trillium erectum*, 266–272
- Trirhabda virgata* (beetle), 348
- tritrophic cascades, 17–19
- tritrophic food chains
 - adaptive prey trait modification (APTM), 141
- tritrophic forest food web, 118–121
- tritrophic interactions
 - in natural systems, 107–108
- tritrophic perspective, 107–108
- trophic cascades, 3, 140
 - herbivore-initiated bottom-up cascades, 162–164
 - trait-mediated, 37–40
 - tritrophic food chains, 141
- trophic control
 - bottom-up view, 325
 - middle of food chains, 325–331
 - top-down view, 324–325
- trophic interactions, 317
 - genetic basis, 304–307
- tunicates, 400
- two predator–one prey webs, 142
 - adaptive prey trait modification (APTM), 141–142
- two-spotted spider mite (*Tetranychus urticae*), 436, 439–440, 442–443, 443–445
- Typhlodromalus aripo* (predatory mite), 440–442
- Tyria jacobaeae* (cinnabar moth), 454
- Uroleucon nigrotuberculatum* (aphid), 169–170
- Uroleucon rudbeckiae* (aphid), 122–124
- USA National Phenology Network (NPN), 515
- vertebrates, 402
 - protective symbioses, 401–402
- Vicia faba*, 31–36, 263, 495–496
- volatile compounds produced by plants, 263, 265, 467
 - dimethyl sulfide (DMS), 57
- water fleas, 10
- webs with four or more species, 21–23
- weeds, 454
 - biological controls, 454, 456
- weevil (*Diaprepes abbreviatus*), 452
- western flower thrips, 439–440
- whelks
 - Acanthina angelica*, 62
 - effects on barnacle prey, 15
 - responses to introduced species, 58–59
- white clover, 230
- whitebark pine (*Pinus albicaulis*), 285
- whitefly (*Bemisia tabaci*), 442
- wild parsnip, 217
- willow galls, 111
- willows, 15
 - effects of stem-boring moth, 15, 22
 - Salix eriocarpa*, 167–168
 - Salix gilgiana*, 167–168
 - Salix serissaefolia*, 167–168
- within-generation phenotype selection, 11–12, 16
- wolves
 - effects of reintroduction, 13, 37
- Yellowstone National Park
 - effects of wolf reintroduction, 13, 37
- Yersinia pestis*, 401
- Zea mays* (corn), 453, 496
- zooplankton, 10, 22
 - ciliates and flagellates, 56
 - release of dimethyl sulfide (DMS), 57
 - vertical migrations, 55–56
- Zostera marina*, 383