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Dorid Nudibranchs Used as Human Food.

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Two trends dominate the research on exotic natural products: the search for traditional foods and original food organisms to recover variety within the increasingly uniform and industrialized foodstuffs, and the search for biologically active chemicals for pharmaceutical purposes. Regarding nudibranchs, the latter are especially interesting because of their ability to accumulate and sometimes modify those highly desired „anti“ substances of their prey organisms (e.g. reviews by Karuso, 1987; Avila, 1995). Using these chemicals (and some other strategies) for self-defense, nudibranchs generally need not fear any predators but a few other opisthobranchs specialized in feeding on their relatives (see Todd, 1981). Humans, other than biochemists, were thought to be no threat as predators. A single exception is the tradition of using the dendronotacean *Tochuina tetraquetra* (Pallas, 1788) as human food on Kuril Islands, Russia (Behrens, 1991). Consumption of the Chilean cryptobranch *Doris amarilla* Pöppig, 1829 „amongst the poorest Indians“ in central Chile at the beginning of the last century (Pöppig, 1829) was regarded as an act of desperation which has, fortunately, stopped long ago (Schrödl, 1996b).

However, recently I was informed by fishermen and a marine biologist that yellowish to orange, rather flat dorids, are still occasionally eaten in the area near Valdivia, southern Chile, not due to famine but as a part of mixed seafood dishes of the locals. One species used is *Gargamella immaculata* Bergh, 1894 (see Schrödl 1996a, 1997 for redescriptions), a locally abundant, sponge feeding cryptobranchiate dorid. With its flattened shape and smaller size it is probably not the dorid referred to by Pöppig's inadequate *D. amarilla* description, but it surely shares all the digestive disadvantages described for that species earlier (Schrödl, 1996b). This is why viscera are usually removed in preparing *Gargamella immaculata*. The remaining body is served raw with lemon or hot chili salsa, or cooked together with other seafood and some vegetables. Similarities to my fictitious menu preparation (Schrödl, 1996b) are striking, the most important appear to be citric acid and anesthetic salsa to neutralize thousands of

needle-like calcareous spicules posthumously trying to protect the dinner's body. Well, how is the taste? "It depends" I was told, and I understood: poor research student, poor mankind, lucky *Gargamella!*

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A summary of the prey of nudibranch molluscs from Cape Arago, Oregon.

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INTRODUCTION

Nudibranchs are diverse predators in many marine benthic communities. However, few studies have attempted to determine the prey of all nudibranch species occurring in a specific locality, and none have done so for sites on the west coast of North America. Information of this kind is necessary to address questions of geographic variation in diet specificity and competition, and is also of use to ecologists and natural products chemists studying the sources of the dazzling array of defensive metabolites found in these shell-less predators (see reviews by Faulkner & Ghiselin, 1983 and Faulkner, 1992).

Since 1980 I have been studying the diets of the nudibranchs found in the rocky intertidal at Cape Arago and on floating docks in neighboring Coos Bay. Results have now been obtained for 50 of the 55 species known from these habitats (see Goddard, 1984, 1990, 1997 for a description of the nudibranch fauna) and are summarized below. The records presented herein include and expand upon those in Goddard (1984, Table 2). Quantitative data obtained on diet specificity and prey preferences of the sponge-feeding dorid nudibranchs will be presented elsewhere and only briefly referred to below.

METHODS

Prey species were determined by observing close association between a nudibranch and a potential prey species, followed by observations of feeding and ingestion in the field and (or) laboratory. Prey species were also identified by microscopic examination of gut

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contents and fecal strands of both field-collected specimens and specimens held with a variety of potential prey in the laboratory. The latter were held in flow-through seawater at ambient temperature (generally 11-13°C). Nudibranchs were identified using Marcus (1961), MacFarland (1966), McDonald & Nybakken (1980), McDonald (1983), and Behrens (1991). Prey species were identified using Osburn (1950, 1952) (bryozoans), Bakus (1966) (poeciloscleridan sponges), and the keys in Kozloff (1996) and Smith & Carlton (1975). Nomenclature generally follows Behrens (1991) and Kozloff (1996).

RESULTS

Prey species are listed in Table 1 for 50 species of nudibranchs known from the Cape Arago/Coos Bay area. *Catriona rickettsi*, which is known in Oregon only from the south jetty at the Umpqua River, 42 km north of Cape Arago (Goddard, 1997), is also included. A prey species followed by (lab) indicates that ingestion of that species was observed only in the laboratory. Prey species preceded by the word 'on' indicate that the nudibranch was found on the listed species, but was not actually observed feeding on it. Prey species followed by (bay) indicate records limited to docks in Coos Bay; all other records apply to the rocky intertidal at Cape Arago.

Table 1. Prey of nudibranchs from the Cape Arago/Coos Bay area (43°18'22"N, 124°24'11"W). Taxonomic authorities for the taxa listed are given at the end of the table.

Species of nudibranch	Prey species
Nudibranchia, Doridacea	
<i>Acanthodoris nanaimoensis</i>	<i>Alcyonidium</i> sp.
<i>Acanthodoris lutea</i>	<i>Alcyonidium</i> sp.
<i>Acanthodoris rhodoceras</i>	<i>Alcyonidium</i> sp.
<i>Adalaria</i> sp. 1 of Behrens (1991)	<i>Hincksina minuscula</i>
<i>Aldisa cooperi</i>	<i>Hymedesmia</i> sp. B of Hartman (1975)
<i>Aldisa sanguinea</i>	<i>Hymedesmia</i> sp. B of Hartman (1975)
<i>Ancula pacifica</i>	<i>Barentsia</i> sp.
<i>Anisodoris lentiginosa</i>	<i>Mycale psila</i> <i>Tedania gurjanovae</i>
<i>Anisodoris nobilis</i>	<i>Antho lithophoenix</i> <i>Halichondria panicea</i> (lab) <i>Hymedesmia</i> sp. A of Hartman (1975) <i>Hymedesmia</i> sp. B of Hartman (1975) <i>Hymedesmia</i> sp. <i>Hymenaphiastra cyanocrypta</i> (yellow form) <i>Hymendectyon lyoni</i> <i>Lissodendoryx firma</i> <i>Lissodendoryx</i> sp. of Austin & Ott (1996) <i>Mycale hispida</i> <i>Mycale macginitiei</i> <i>Mycale psila</i> <i>Myxilla incrustans</i> <i>Ophlitaspongia pennata</i>
	<i>Sigmatocia</i> sp. <i>?Stylopus arndti</i> <i>Tedania gurjanovae</i> <i>?Tedanione obscurata</i> <i>Zygherpe hyaloderma</i>
<i>Archidoris montereyensis</i>	<i>Axocielita originalis</i> (soft, orange form) <i>Halichondria panicea</i> <i>Hymeniacion ungodon</i> <i>Lissodendoryx firma</i> <i>Mycale macginitiei</i> <i>Myxilla incrustans</i> <i>Prosuberites</i> sp. <i>Suberites</i> sp. of Austin & Ott (1996)
<i>Archidoris odhneri</i>	<i>Haliclona</i> sp. <i>Halichondria panicea</i> <i>Hymeniacion ungodon</i> <i>Sigmatocia</i> sp. <i>Suberites</i> sp. of Austin & Ott (1996) <i>Tedania gurjanovae</i>
<i>Cadlina luteomarginata</i>	<i>Aplysilla glacialis</i> <i>Halichondria panicea</i> <i>Hymedesmia</i> sp. A of Hartman (1975) (lab) <i>Hymedesmia</i> sp. <i>Hymendectyon lyoni</i> <i>Lissodendoryx firma</i> <i>Lissodendoryx</i> sp. of Austin & Ott (1996) <i>Mycale hispida</i> (lab) <i>Mycale macginitiei</i> <i>Myxilla incrustans</i> <i>Pleraplysilla</i> sp. <i>Spongionella</i> sp. of Austin & Ott (1996) <i>?Stylopus arndti</i> <i>Tedania gurjanovae</i> <i>Zygherpe hyaloderma</i>
<i>Cadlina modesta</i>	<i>Aplysilla glacialis</i> <i>Halisarca</i> sp.
<i>Crimora coneja</i>	<i>Hincksina minuscula</i>
<i>Diaulula sandiegensis</i>	<i>Halichondria panicea</i> (lab) <i>Haliclona</i> spp. <i>Mycale macginitiei</i> <i>Myxilla incrustans</i> <i>Neoesperiopsis rigida</i> (lab) <i>Reniera</i> sp. B of Hartman (1975) <i>Sigmatocia</i> sp. <i>Toxadocia</i> sp. <i>Xestospongia vanilla</i>
<i>Doridella steinbergae</i>	<i>Membranipora membranacea</i> (bay)
<i>Geitodoris heathi</i>	<i>Mycale macginitiei</i> <i>Mycale psila</i> (lab)
<i>Hallaxa chani</i>	<i>Halisarca</i> sp.
<i>Laila cockerelli</i>	<i>Hincksina velata</i>
<i>Onchidoris bilamellata</i>	<i>Balanus glandula</i> (bay)
<i>Onchidoris muricata</i>	<i>Eurystomella bilabiata</i> <i>Hincksina minuscula</i> <i>Microporella cribosa</i> <i>Rhyncozoon</i> sp. on <i>Dendrobeania lichenoides</i> on <i>Membranipora membranacea</i> (bay)
<i>Polycera atra</i>	<i>Bugula pacifica</i> (bay)
<i>Rostanga pulchra</i>	<i>Antho lithophoenix</i> <i>Clathria</i> sp. <i>Ophlitaspongia pennata</i> on <i>Axocielita originalis</i> on <i>Hymedesmia</i> sp. A of Hartman (1975) on <i>Microcionia</i> sp. on <i>Plocamia karykina</i> on <i>Plocamilla lambei</i>
<i>Triopha catalinae</i>	<i>Bugula pacifica</i>

	<i>Crisia serrulata</i> <i>Crisia</i> spp. <i>Dendrobeatia lichenoides</i> <i>Filicrisia</i> sp. <i>Tricellaria occidentalis</i> <i>Tricellaria ternata</i>
<i>Triopha maculata</i>	<i>Bugula pacifica</i> (lab) <i>Crisia serrulata</i> (lab) <i>Dendrobeatia lichenoides</i> <i>Tricellaria erecta</i> <i>Tricellaria occidentalis</i>
Nudibranchia, Dendronotacea	
<i>Dendronotus albus</i>	<i>Abietinaria</i> sp. (<i>A. anguina</i> of Ricketts et al., 1985, fig. 86)
<i>Dendronotus frondosus</i>	<i>Obelia</i> spp.
<i>Dendronotus subramosus</i>	<i>Aglaophenia</i> sp.
<i>Doto amyra</i>	<i>Abietinaria</i> sp. (<i>A. anguina</i> of Ricketts et al., 1985, fig. 86)
<i>Doto kya</i>	among <i>Plumularia</i> sp. and small, thecate hydroids
<i>Doto</i> form B of Goddard (1996)	<i>Aglaophenia</i> sp.
<i>Tochuina tetraquetra</i>	next to <i>Alcyonium rudyi</i>
<i>Tritonia festiva</i>	<i>Alcyonium rudyi</i> "Clavularia sp." of Ricketts et al. (1985, fig. 162) <i>Gersemia rubiformis</i> (lab)
Nudibranchia, Arminacea	
<i>Dirona albolineata</i>	<i>Bugula pacifica</i> (lab)
<i>Dirona aurantia</i>	<i>Bugula pacifica</i> (lab)
<i>Dirona picta</i>	unidentified arborescent bryozoans
<i>Janolus fuscus</i>	<i>Bugula pacifica</i> <i>Tricellaria erecta</i> (lab) <i>Tricellaria occidentalis</i>
Nudibranchia, Aeolidacea	
<i>Aeolidia papillosa</i>	<i>Anthopleura elegantissima</i> (lab) <i>Anthopleura xanthogrammica</i> (lab) <i>Epiactis lisbethi</i> (lab) <i>Epiactis prolifera</i> <i>Diadumene lineata</i> (lab) <i>Metridium senile</i> (bay) <i>Urticina crassicornis</i> (lab)
<i>Catriona columbiana</i>	<i>Tubularia</i> sp.
<i>Catriona rickettsi</i> ¹	<i>Tubularia</i> sp.
<i>Cumanotus fernaldi</i> ²	<i>Tubularia crocea</i> (bay)
<i>Cuthona abronia</i>	among small thecate hydroids
<i>Cuthona albocrusta</i>	among small thecate hydroids
<i>Cuthona cocoachroma</i>	<i>Thuiaria</i> sp.
<i>Cuthona divae</i>	<i>Hydractinia</i> sp.
<i>Cuthona fulgens</i>	<i>Sarsia</i> sp.
<i>Eubranthus olivaceus</i>	<i>Plumularia</i> sp.
<i>Eubranthus rustyus</i>	<i>Plumularia</i> sp.
<i>Flabellina trilineata</i>	<i>Eudendrium californicum</i> <i>Tubularia</i> sp.
<i>Hermisenda crassicornis</i>	<i>Botryllus aurantius</i> <i>Tubularia crocea</i> (lab) <i>Tubularia</i> sp.

Tenellia adspersa *Gonothyrea* sp. (bay)
Tubularia crocea (bay)

1 Specimens from the south jetty, mouth of the Umpqua River, Douglas County, OR (Goddard, 1997).

2 Two species of *Cumanotus* exist in the northeastern Pacific (S. Millen, personal communication, 1997). Specimens found on docks in Coos Bay lack cephalic tentacles and lay spiral egg masses (personal observations).

Taxonomic authorities (nudibranchs): *Acanthodoris nanaimoensis* O'Donoghue, 1921; *A. lutea* MacFarland, 1925; *A. rhodoceras* Cockerell in Cockerell & Eliot, 1905; *Aeolidia papillosa* (Linnaeus, 1761); *Aldisa cooperi* Robilliard & Baba, 1972; *Aldisa sanguinea* (Cooper, 1863); *Ancula pacifica* MacFarland, 1905; *Anisodoris lentiginosa* Millen, 1982; *A. nobilis* (MacFarland, 1905); *Archidoris montereyensis* (Cooper, 1863); *A. odhneri* (MacFarland, 1966); *Cadlina luteomarginata* MacFarland, 1966; *C. modesta* MacFarland, 1966; *Catriona columbiana* (O'Donoghue, 1922); *C. rickettsi* Behrens, 1984; *Crimora coneja* Marcus, 1961; *Cumanotus fernaldi* Thompson & Brown, 1984; *Cuthona abronia* (MacFarland, 1966); *C. albocrusta* (MacFarland, 1966); *C. cocoachroma* Williams & Gosliner, 1979; *C. divae* (Marcus, 1961); *C. fulgens* (MacFarland, 1966); *Dendronotus albus* MacFarland, 1966; *D. frondosus* (Ascanius, 1774); *D. subramosus* MacFarland, 1966; *Dialula sandiegensis* (Cooper, 1863); *Dirona albolineata* Eliot in Cockerell & Eliot, 1905; *D. aurantia* Hurst, 1966; *D. picta* MacFarland in Cockerell & Eliot, 1905; *Doridella steinbergae* (Lance, 1962); *Doto amyra* Marcus, 1961; *D. kya* Marcus, 1961; *Eubranthus olivaceus* (O'Donoghue, 1922); *E. rustyus* (Marcus, 1961); *Flabellina trilineata* (O'Donoghue, 1921); *Geitodoris heathi* (MacFarland, 1905); *Hallaxa chani* Gosliner & Williams, 1975; *Hermisenda crassicornis* (Eschscholtz, 1831); *Janolus fuscus* O'Donoghue, 1924; *Laila cockerelli* MacFarland, 1905; *Onchidoris bilamellata* (Linnaeus, 1767); *O. muricata* (Müller, 1776); *Polycera atra* MacFarland, 1905; *Rostanga pulchra* MacFarland, 1905; *Tenellia adspersa* (Nordmann, 1845); *Tochuina tetraquetra* (Pallas, 1788); *Triopha catalinae* (Cooper, 1863); *T. maculata* MacFarland, 1905; *Tritonia festiva* (Stearns, 1873).

Taxonomic authorities (prey species): *Abietinaria anguina* (Trask); *Alcyonium rudyi* Verseveldt & van Ofwegen, 1992; *Antho lithophoenix* (de Laubenfels, 1927); *Anthopleura elegantissima* (Brandt, 1835); *A. xanthogrammica* (Brandt, 1835); *Axocelita originalis* (de Laubenfels, 1930); *Balanus glandula* Darwin, 1854; *Botryllus aurantius* Oka, 1927; *Bugula pacifica* Robertson, 1905; *Crisia serrulata* (Gabb & Horn, 1862); *Dendrobeatia lichenoides* (Robertson, 1905); *Diadumene lineata* (Verrill, 1873); *Epiactis lisbethi* Fautin & Chia, 1986; *E. prolifera* Verrill, 1869; *Eudendrium californicum* Torrey, 1902; *Eurystomella bilabiata* (Hincks, 1884); *Gersemia rubiformis* (Ehrenberg, 1834); *Halichondria panicea* (Pallas, 1766); *Hincksina minuscula* (Hincks, 1882); *H. velata* (Hincks, 1881); *Hymenamphiasira cyanocrypta* de Laubenfels, 1930; *Hymendectyon lyoni* Bakus, 1966; *Hymeniacion ungodon* de Laubenfels, 1932; *Lissodendoryx firma* (Lambe, 1895); *Membranipora membranacea* (Linnaeus, 1767); *Metridium senile* (Linnaeus, 1767); *Microporella cribosa* Osburn, 1952; *Mycale hispida* (Lambe, 1893); *M. maccintiei* de Laubenfels, 1930; *M. psila* (de Laubenfels, 1930); *Myxilla incrustans* (Esper, 1805-14); *Neoesperiopsis rigida* (Lambe, 1893); *Ophlitaspongia pennata* (Lambe, 1893); *Plocamia karykina* (de Laubenfels, 1927); *Plocamilla lambei* Burton, 1935; *?Stylopus arndti* (de Laubenfels, 1930); *Tricellaria erecta* (Robertson, 1900); *T. occidentalis* (Trask, 1857); *T. ternata* (Solander, 1786); *Tedania gurjanovae* Koltun, 1958; *?Tedanione obscurata* de Laubenfels, 1930; *Tubularia crocea* (L. Agassiz, 1862); *Urticina crassicornis* (Müller, 1776); *Xestospongia vanilla* (de Laubenfels, 1930); *Zygherpe hyaloderma* de Laubenfels, 1932.

DISCUSSION

Nudibranchs from Cape Arago that specialize throughout their ranges on single species of prey include *Crimora coneja*, *Hallaxa chani*, *Laila cockerelli*, *Cuthona cocoachroma*, and possibly also *Adalaria* sp. 1 of Behrens (1991), *Ancula pacifica*, and species of *Acanthodoris* (McDonald, 1983; Goddard, 1981, 1984, 1985, 1987; Goddard et al., 1997; present study). Generalists with broad diets include *Anisodoris nobilis*, *Archidoris montereyensis*, *Cadlina luteomarginata*, *Dialula sandiegensis*, *Onchidoris muricata*, *Rostanga pulchra*, *Triopha catalinae*, *T. maculata*, and *Aeolidia papillosa*.

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Generalist species, however, may specialize locally or as individuals (Fox & Morrow, 1981; Hall et al., 1984), or show strong preferences for particular prey. For example, most *Aeolidia papillosa* from Cape Arago prey on *Epiactis prolifera*, while those on floating docks in Coos Bay prey primarily on *Metridium senile*. Similarly, *Anisodoris nobilis* from Cape Arago are usually found on and prefer *Mycale macginitiei* over other sponges, while *Cadlina luteomarginata* prey preferentially on *Aplysilla glacialis* (Goddard, unpublished data).

Some of the aeolids found in the Cape Arago area co-occur on the same species of hydroids but prey on different portions. Thus, *Catriona columbiana* preys suctorially on the basal stolons of *Tubularia* sp., *Catriona rickettsi* preys suctorially on the stalks, and *Flabellina trilineata* consumes the hydranths (personal observations). A similar partitioning of food resources was noted by Hirano et al. (1987) for *Eubranchus olivaceus* and *E. rustyus* preying on *Plumularia* sp. at Cape Arago.

Local diets of 5 species have yet to be determined. These include: *Acanthodoris hudsoni* MacFarland, 1905, *Cuthona flavovulva* (MacFarland, 1966), *Dendronotus iris* Cooper, 1863, *Melibe leonina* (Gould, 1852), and *Palio zosteriae* (O'Donoghue, 1924). *Cuthona flavovulva* has been reported on unidentified hydroids, on which it likely feeds; *Dendronotus iris* is known to prey on ceriantharian anemones; *Melibe* uses an expanded oral hood to capture small crustaceans; and *Palio zosteriae* has been reported to feed on bryozoans, including *Membranipora membranacea* (Rivest, 1984; and see summaries in McDonald, 1983). No data exists on the diet of *Acanthodoris hudsoni*. However, based on its radular morphology, this species likely preys on fleshy ctenostomate bryozoans and possibly also colonial ascidians (Nybakken & McDonald, 1981). *Dendronotus albopunctatus* Robilliard, 1972 is also known from Coos Bay, but only subtidally (Goddard, 1990), and nothing is known about its diet.

The diets of some of the hydroid-feeding species, especially species of *Cuthona*, are still incompletely known, and future work at Cape Arago should focus on them.

ACKNOWLEDGEMENTS

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EDITOR'S NOTES

Thanks for all of the bibliography and links which have been sent recently. I have made a major update to the bibliography on the Internet. More will be done soon including adding many more non-nudibranch publications thanks to Paula Mikkelsen and Gary McDonald.